

# Magnetar outbursts: an observational review

Nanda Rea & Paolo Esposito

**Abstract** Transient outbursts from magnetars have shown to be a key property of their emission, and one of the main way to discover new sources of this class. From the discovery of the first transient event around 2003, we now count about a dozen of outbursts, which increased the number of these strongly magnetic neutron stars by a third in six years. Magnetars’ outbursts might involve their multi-band emission resulting in an increased activity from radio to hard X-ray, usually with a soft X-ray flux increasing by a factor of 10–1000 with respect to the quiescent level. A connected X-ray spectral evolution is also often observed, with a spectral softening during the outburst decay. The flux decay times vary a lot from source to source, ranging from a few weeks to several years, as also the decay law which can be exponential-like, a power-law or even multiple power-laws can be required to model the flux decrease. We review here on the latest observational results on the multi-band emission of magnetars, and summarize one by one all the transient events which could be studied to date from these sources.

## 1 Authors’ preface

The magnetar field have been recently boosted by the discovery of transients magnetars, and more in general by their possible role in gamma-ray bursts and gravitational wave researches. However, probably “because” of the rapid development of the field, there is still a large confusion in the literature on when a source can be labelled as a magnetar candidate, and what exactly this word means: is the super-

---

Nanda Rea

Institut de Ciències de l’Espai (CSIC-IEEC), Campus UAB, Facultat de Ciències, Torre C5-parell 2a planta, Bellaterra (Barcelona), Spain; e-mail: [rea@ice.csic.es](mailto:rea@ice.csic.es)

Paolo Esposito

Osservatorio Astronomico di Cagliari, località Poggio dei Pini, strada 54, 09012, Capoterra, Italy; e-mail: [paoloesp@oa-cagliari.inaf.it](mailto:paoloesp@oa-cagliari.inaf.it)

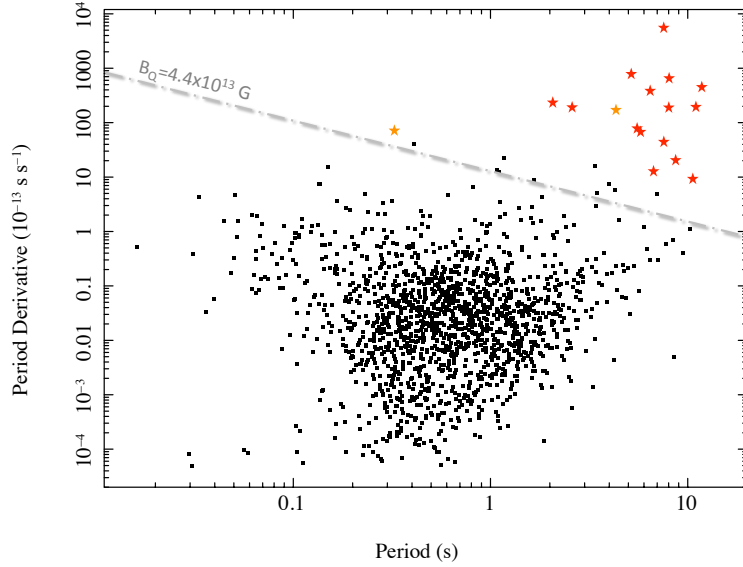
critical dipolar magnetic field which defines a magnetar? Is the bursting behavior? Is the low rotational power with respect to their X-ray luminosity? Is the black-body plus power-law X-ray spectrum? Is the erratic radio pulsed behavior? When do we define a source an Anomalous X-ray Pulsar (AXP) or a Soft Gamma Repeater (SGR)? Apparently in the recent literature, even groups working in the magnetar field since decades are not fully in agreement with their exact definition: see the archetypical example of the i) AXP 1E 1547–5408 = SGR 1550–5418 = PSR J1550–5418 which has been discovered only 3 years ago and it already has three names, ii) PSR J1846–0258 which showed all the typical magnetar-like activity but it is still labelled as a fully rotational powered pulsar since as such it was first discovered, or iii) SGR 0418+5729 which shows all the typical magnetar emission properties but it has a magnetic field in line with normal pulsars. Most of the questions above can be answered with a counter-example, it is then indeed becoming very difficult to give a definitive and unique answer on when we can call a source an AXP, an SGR, or a magnetar in general.

With this preface we aim at warning non-expert readers on the assumption and conceptual choices we will make in this review. In particular, this is a pure observational review, mainly focussed on transients. We will then enter very little in the theoretical interpretations. We will not discuss about X-ray bursts or flares, but only about the outbursts of the persistent emission of these sources. Furthermore, a part from the historical section, we will consider hereafter AXPs and SGRs as the same class of sources, calling them “magnetar candidates”. We apologize in advance if from time to time we drop the “candidate” label in the text, but this is only due an easier writing. We will include PSR 1622–4950 and PSR J1846–0258 in the magnetar list, given the discovery of their magnetars-like behavior, which clearly shows that (at least occasionally) they cannot be only rotational powered.

This review is structured as follow: a brief historical overview followed by the description of the multi-band emission of magnetars (with detailed numbers reported in the two tables rather than in the text). Then, we report one by one on all magnetars’ outburst observed to date.

## 2 A bit of history

Neutron stars are the debris of the supernova explosion of massive stars, the existence of which was first theoretically predicted around 1930 [13, 2] and then observed for the first time more than 30 years later [64]. We now know many different flavors of these compact objects, and many open questions are still waiting for an answer after decades of studies. The neutron star world is mainly populated by the radio pulsars and the binary pulsars (thousands of objects), however in the last decades also extreme and puzzling small sub-classes of neutron stars were discovered: Anomalous X-ray Pulsars (AXPs), Soft Gamma Repeaters (SGRs), Rotating Radio Transients (RRATs), X-ray Dim Isolated Neutron Stars (XDINs), and Central Compact Objects (CCOs). The large amount of different acronyms might al-



**Fig. 1** Diagram of the  $P-\dot{P}$  of all isolated pulsars known to date. Stars represents all sources which showed magnetar activity: in red all SGRs and AXPs having a measurement of the spin period and its derivative, and in orange PSR J1846–0258 and PSR 1622–4950.

ready show how diverse is the neutron star class, and on the other hand, how far we are from a unified scenario. In particular, despite being presumably governed by a single equation of state, the neutron star zoo manifests itself as a puzzling multicolored class, whose bewildering variety of observational properties is still largely unexplained. These objects are amongst the most intriguing populations in modern high-energy astrophysics and in physics in general. In fact, besides being interesting themselves in terms of studying the neutron star equation of state and the physical processes and mechanisms involved in their emission, they are precious places to test gravitational and particle physics, relativistic plasma theories, as well as strange quark states of matter and physics of atoms and molecules embedded in extremely high magnetic fields (impossible to be reproduced on Earth). The focus of this review is the outburst emission of strongly magnetized neutron stars, having magnetic fields close or stronger than the electron critical magnetic field of  $B_{\text{crit}} = m_e^2 c^3 / e \hbar \sim 4.4 \times 10^{13}$  Gauss, at which the cyclotron energy of an electron reaches the electron rest mass energy.

### 3 General observational characteristics

Before presenting these ultra-magnetic objects, it is instructive to indicate how the magnetic field of isolated pulsars is estimated. Assuming that the spin-down torque is due to magnetic dipole radiation, the surface magnetic field can be estimated from the measured pulsar spin period  $P$  and its derivative  $\dot{P}$ , for each pulsar:

$$B_{\text{surface}} = (3 I c^3 \dot{P} P / 8\pi^2 R^6)^{1/2} \sim 3.2 \times 10^{19} (P\dot{P})^{1/2} \text{ Gauss}$$

(where  $P$  is in units of seconds, and  $I \sim 10^{45} \text{ g cm}^2$  and  $R \sim 10^6 \text{ cm}$  are the assumed neutron star moment of inertia and radius). Presently there are almost 1800 spin-down powered radio pulsars known, with periods from about 1.5 ms to 8 s [97], and on average they have magnetic fields of  $\sim 10^{12}$  Gauss. However, beside the magnetar candidates which are the topic of this review, there are also a handful of radio pulsars and other newly discovered type of pulsars having super critical magnetic fields ( $> B_{\text{crit}}$ ): namely the high-B pulsars, a few XDINSs and RRATs. We will not report on those in this review, however we want to point out that they might represent somehow quiescent or evolved magnetars. The “magnetars” are a small group of X-ray pulsars (about twenty objects with spin periods between 2–12 s) the emission of which is very hardly explained by any of the common scenario for the radio pulsar or the X-ray binary pulsar populations [101]. In fact, the very strong X-ray emission of these objects is too high and variable to be fed by the rotational energy alone (as in the radio pulsars), and no evidence for a companion star has been found so far in favor of any accretion process (as in the X-ray binary systems). Moreover, roughly assuming them being magnetic dipole radiator, their inferred magnetic fields appear to be as high as  $B \sim 10^{14} - 10^{15}$  Gauss, definitely larger than the quantum electron critical magnetic field limit  $B_{\text{crit}}$ . Because of these high B fields, the emission of magnetars is thought to be powered by the decay and the instability of these strong fields [23, 144], but despite valuable recent theories [143, 4] a complete physical interpretation of all different aspects of their emission is still missing. Very interestingly, the magnetars are also characterized by catastrophic and peculiar X-ray bursting, flaring and outbursting events where luminosities of the order of  $10^{46} \text{ erg s}^{-1}$  are reached. In Tables 1 and 2 we list the main characteristics of magnetars, and in the rest of this review we discuss one by one the multi-band properties of these objects, finishing with reviewing their transient activity as known to date.

### 4 Multi-band view of magnetars

Until about 10 years ago, magnetars were thought to be emitting exclusively in the X-ray energy range, while having sporadic flares reaching the soft  $\gamma$ -ray energies. It was only recently that the availability of new instruments, as well as a progressively better understanding of these objects, prompted the search and the following dis-

**Table 1** Accurate positions and timing characteristics of magnetars.

Magnetars	RA (J2000)	Dec (J2000)	$P$ (s)	$\dot{P}_{-12}$ ( $s/s$ )	$B_{14}$ (G)	$d^b$ (kpc)
1E 2259+586 <sup>o</sup>	23 01 08.29	+58 52 44.45	6.98	0.5	0.6	3.0
4U 0142+614 <sup>o</sup>	01 46 22.44	+61 45 03.3	8.69	2.0	1.3	3.0
1RXS J1708–4009	17 08 46.87	-40 08 52.44	10.99	24*	4.7	3.8
1E 1048.1–5937 <sup>o</sup>	10 50 07.14	-59 53 21.4	6.45	50*	4.4	2.7
1E 1841–045	18 41 19.34	-04 56 11.16	11.77	41	7.1	7.0
CXOU J0100–7211	01 00 43.14	-72 11 33.8	8.02	19	3.9	60
CXOU J1647–4552 <sup>o</sup>	16 47 10.2	-45 52 16.9	10.61	0.9*	1.3	5.0
XTE J1810–197 <sup>o</sup>	18 09 51.08	-19 43 51.74	5.54	10*	1.6	2.5
1E 1547–5408 <sup>o</sup>	15 50 54.11	-54 18 23.7	2.07	23 *	2.2	4.0
CXOU J1714–3810	17 14 05.74	-38 10 30.9	3.82	59	4.8	8.0
SGR 1806–20 <sup>o</sup>	18 08 39.33	-20 24 39.94	7.55	10*	18	15
SGR 1900+14	19 07 14.33	+09 19 20.1	5.17	100*	6.5	15
SGR 0526–66	05 26 00.89	-66 04 36.3	8.05	65	7.3	55
SGR 1627–41 <sup>o</sup>	16 35 51.84	-47 35 23.3	2.59	19	2.2	11
SGR 0501+4516 <sup>o</sup>	05 01 6.78	+45 16 34.0	5.76	6.8	2.0	5.0
SGR 0418+5729 <sup>o</sup>	04 18 33.86	+57 32 22.91	9.08	<0.006	<0.075	2.0
SGR 1833–0832 <sup>o</sup>	18 33 44.38	-08 31 07.71	7.56	4.0	1.8	10
PSR 1622–4950	16 22 44.8	-49 50 54.4	4.32	17	2.8	9.0
PSR J1846–0258	18 46 24.94	-02 58 30.1	0.32	7.1	0.5	6.0
AX J1844–0258 <sup>o,a</sup>	18 44 54.68	-02 56 53.1	6.97	-	-	8.5

\* Variable parameters; see <http://www.physics.mcgill.ca/~pulsar/magnetar/main.html> for some of the alternative values.

<sup>o</sup> Sources which showed outburst activity (discussed in § 5).

<sup>a</sup> Candidate magnetar.

<sup>b</sup> We report here on the most recent values for the distances, however we caveat that for most of these objects the distance determination is very uncertain or controversial. We used these distances to infer the luminosity in Tab. 2, which can be easily scaled if in the future more precise distances will be available.

covery of their emission at other wavelengths. Below we summarize the multi-band properties of magnetars.

#### 4.1 Radio emission of magnetars

For a long time magnetar candidates were thought to be radio quiet. However, their radio detections started about ten years ago, when radio observations of one SGR (SGR 1806–20) performed with the Very Large array (VLA), revealed the presence of elongated structures with a variable shape and orientation over a year timescale [154, 41]. These jet-like features suggested that outflows from SGR 1806–20 have been occurring, most probably connected with its conspicuous bursting and flaring activity. In fact, after a few years transient radio emission were discovered from SGRs which showed giant flares (see [134, 101] and reference therein). Only three

these events were detected in the last 30 years and after two of them a transient radio counterpart was discovered [40, 42], while in the first case no data were available. In particular, radio observations after the recent giant flare from SGR 1806–20 [120, 67] clearly showed a radio structure moving out from the source and changing in polarization, believed to be an outflow [49, 141, 38].

Furthermore, recently pulsed radio emission were also discovered in a few magnetars. The first detection of pulsed radio emission was from the transient AXP, XTE J1810–197, which has been first detected in the radio band as a continuum source (4.5 mJy; [60]), and soon after recognized as a radio pulsar [10, 8]. Another transient AXP has been observed to show radio pulsed emission, 1E 1547–5408 [9], with similar characteristics as the XTE J1810–197. In particular, in radio magnetars show many properties at variance with canonical radio pulsars, as a flat spectrum, large flux variability (until a factor of  $\sim 10$ ) on timescales as short as fraction of hours, and a transient behaviour thought to be connected with the X-ray outburst of the source.

However, the discovery of the third radio magnetar, PSR 1622–4950 [96], has instead showed that the strong connection between the transient pulsed radio emission and the X-ray outbursts of magnetar candidates does not always necessarily hold. In fact PSR 1622–4950 has shown in the past 7 years all typical radio-magnetar emission, it has a field of  $B \sim 3 \times 10^{14}$  Gauss, but its X-ray counterpart was never detected in outburst thus far.

For almost all other magnetars deep upper limits were derived on their radio pulsed emission [6, 16, 33].

## 4.2 Optical and infrared emission of magnetars

The availability of large telescopes as the Very Large Telescope, Gemini or Keck, made it feasible the detection of the weak optical and infrared counterparts to magnetar candidates (see [110] for a recent review). Furthermore, the new adaptive optics technology allowed the detection of such counterparts even in the very crowded regions of the Galactic plane.

The first discovery of such counterparts was ten years ago, with the detection of 4U 0142+614 in the optical band [65].

An exact modeling of the entire spectral energy distribution of a magnetar has not yet been done. In the low energy bands, an infrared “excess” (or “flattening”) is seen with respect to the extrapolation of the blackbody often used to account for the optical emission. However, instead if we connect the infrared points with the non-thermal hard X-ray observations (as for the typical radio pulsars), we end up with an excess in the optical band. Thus, whether this optical and infrared emission comes from a thermal process or not is still unclear and would be an important information for constraining the models: in fact, if this emission comes from a disk it is expected to be thermal [123], while if it comes from processes on the magnetosphere of a magnetars we expect the optical spectral continuum to be non thermal [29].

**Table 2** X-ray spectral properties and luminosities in different wavebands.

Magnetar	$kT_1/kT_2$ (keV)	$\Gamma_1$	$\Gamma_2$	$L_{35,\text{soft}}^b$ (erg s <sup>-1</sup> )	$L_{35,\text{hard}}^b$ (erg s <sup>-1</sup> )	$S d^2$ (mJy kpc <sup>2</sup> )	$K_x$ mag	References
1E 2259+586 <sup>o</sup>	0.4*	4.1*	—	0.2*	—	—	21.7*	[161, 140]
4U 0142+614 <sup>o</sup>	0.4*	3.9*	0.9*	3*	0.6*	—	19.7	[128, 20, 66]
1RXS J1708–4009	0.5*	3*	1.1*	1.4*	0.7	—	—	[131, 130, 58]
1E 1048.1–5937 <sup>o</sup>	0.6*	3.4*	—	0.08*	—	—	19.4*	[148, 156]
1E 1841–045	0.4	2	1.5	2.6	2.6	—	—	[112, 57]
CXOU J0100–7211	0.3/0.7	—	—	1.5	—	—	—	[145]
CXOU J1647–4552 <sup>o</sup>	0.6*	2.3*	—	2.5*	—	—	—	[73]
XTE J1810–197 <sup>o</sup>	0.3/0.7*	—	—	0.35*	—	80*	20.8*	[53, 10, 79]
1E 1547–5408 <sup>o</sup>	0.6*	1.7*	1.5*	1.6*	2.4*	40*	18.5*	[9, 80, 27]
CXOU J1714–3810	0.38	3.4	—	0.2	—	—	—	[61]
SGR 1806–20 <sup>o</sup>	0.8*	1.2*	2	12*	12*	—	19.3*	[102, 70]
SGR 1900+14	0.5*	1.9*	3.1	2.3*	4	—	—	[104, 57]
SGR 0526–66	—	3.3	—	4	—	—	—	[146]
SGR 1627–41 <sup>o</sup>	0.5*	0.6*	—	0.15*	—	—	—	[37]
SGR 0501+4516 <sup>o</sup>	0.7*	2.9*	0.8	1.8*	1.1*	—	19.1	[127, 135]
SGR 0418+5729 <sup>o</sup>	0.9*	2.6*	—	0.042*	—	—	—	[32, 33, 125]
SGR 1833–0832 <sup>o</sup>	1.2	—	—	0.9*	—	—	—	[33]
PSR 1622–4950	0.3	—	—	0.018	—	390*	—	[96]
PSR J1846–0258	0.9*	1.9*	2 <sup>c</sup>	3.1*	2.8 <sup>c</sup>	—	—	[117, 95, 99]
AX J1844–0258 <sup>o,a</sup>	0.6	—	—	1*	—	—	—	[55]

\* Variable parameters; see <http://www.physics.mcgill.ca/~pulsar/magnetar/main.html> for some of the alternative values.

<sup>o</sup> Sources which showed outburst activity (discussed in § 5).

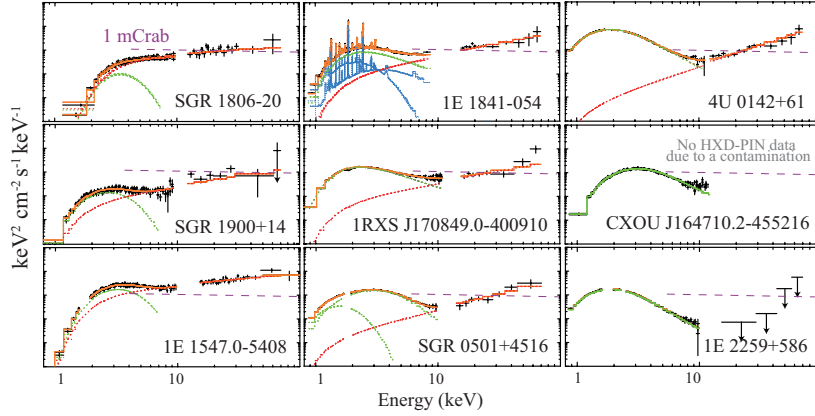
<sup>a</sup> Candidate magnetar.

<sup>b</sup> The soft and hard X-ray luminosities are given in the 1–10 keV and 20–100 keV ranges, and in units of 10<sup>35</sup> erg s<sup>-1</sup>. The radio flux  $S$  is calculated at 1.4 GHz. If only absorbed flux was found in literature or the flux was given for ranges other than 2–10 or 20–100 keV, XSPEC was used to estimate the unabsorbed flux. Luminosities assume the distances given in Table 1.

<sup>c</sup> Including the (dominant) contribution from the pulsar wind nebula, that cannot be resolved from the pulsar emission by the current-generation gamma-ray instruments.

### 4.3 Soft X-ray emission of magnetars

Magnetar X-ray emission may be qualitatively separated into two components, a low-energy, <10 keV, and a higher energy one, >20 keV. It is likely, although not proved yet, that different emission mechanisms are responsible for the two components. The low energy component is typically fit with either a blackbody with a temperature  $kT \sim 0.3\text{--}0.6$  keV and a power-law with a relatively steep photon index,  $\Gamma \sim 2\text{--}4$ , or two blackbodies with  $kT_1 \sim 0.3$  keV and  $kT_2 \sim 0.7$  keV [101]. In a few cases the low-energy component of SGR spectra has been fit with a single power-law, but recent longer observations have shown that, also for these sources, that an additional blackbody component is required [108].



**Fig. 2** Hard X-ray emission of magnetars as observed by Suzaku (from [28]).

Thompson, Lyutikov & Kulkarni [143] first pointed out that resonant scattering in magnetar magnetospheres may explain the non-thermal emission observed in magnetar candidates. Due to the presence of hot plasma in the neutron star cor-  
 nae, the thermal emission from the neutron star surface/atmosphere gets distorted through efficient resonant cyclotron scattering.

Recent applications of resonant scattering models to the soft X-ray emission of magnetars have shown that indeed this interpretation fits well the data [134, 59, 164], and finds that these sources are characterized by magnetospheric plasma with a density which, at resonant radius, is about 3 orders of magnitude higher than the Goldreich-Julian electron density.

#### 4.4 Hard X-ray emission of magnetars

Hard X-ray emission until  $\sim 200$  keV has been discovered for some magnetars (namely 1E 2259+586, 1RXS J1708–4009, 1E 1841–045, SGR 1806–20, SGR 1900+14, 1E 1547–5408, SGR 0501+4516 [90, 89, 108, 20, 57, 127, 27]; see also Figure 2), thanks to INTEGRAL and RXTE. Hard X-ray variability has also been discovered in two cases: for SGR 1806–20, and recently in the SGR 0501+4516 (see [56, 127]). In the two brightest source, a strong variability of the hard X-ray emission with the pulsar phase has been discovered [20, 19].

The discovery of magnetars hard X-ray emission opened a new window in the study of magnetars, making it crucial to revise the current knowledge of magnetars being steady soft X-ray sources. However, despite recent theoretical works [4, 3], a clear physical idea on how this hard X-ray emission is generated is still missing. Very promising are recent models invoking resonant cyclotron scattering in the rel-



ativistic regime [118, 3] although current codes does not allow any observational tests so far.

## 5 Magnetars' Outbursts

In this section we report one by one on the outbursts that have been detected so far from magnetars. We define here as outbursts an increase in the persistent level of at least a factor of 5. However, note that many of the sources not listed below showed smaller outbursts, often connected with bursting activity (as e.g. 1E 1841–045, PSR J1846–0258, and SGR 1900+14; [92, 45, 91, 35, 51]). A comprehensive image of the decay of most these outbursts (the ones successfully followed by X-ray imaging instruments) are reported in Figure 3.

### 5.1 *1E 2259+586*

This 7 s X-ray pulsar was discovered a few decades ago, and it was believed to be a very stable X-ray emitter and pulsator. However, in 2002, it emitted the first notable recorded case of flux variability from a magnetar [83]. Its active phase, with a factor of  $\sim 10$  persistent flux enhancement, was followed by the onset of a bursting activity phase during which the source displayed more than 80 short bursts [46, 161]. Furthermore, despite being the first case of an outburst from an otherwise persistent and quiet magnetar candidate, 1E 2259+586 was also the first to show a connected X-ray and infrared outburst [140]. It showed a glitch during the enhanced activity, corroborating the idea of these outbursts being due to crustal stresses imparted by the unstable magnetic fields [83]. Furthermore, this magnetar lies in the supernova remnant (SNR) G109.1-1.0 (CTB 109), being one of the few associations between magnetars and SNR which still holds [44].

### 5.2 *4U 0142+614*

4U 0142+614 is one of the brightest magnetar known to date, and it was first detected by Uhuru in 1978. However, mainly because of the presence of the accretion-powered binary pulsar RX J0146.9+6121 nearby, only in 1994 was an  $\sim 8.7$  s periodicity reported using EXOSAT data taken in 1984 [77]. Long-term spin-period variations were discovered thanks to a large RXTE campaign [47], leading to the measure of the period derivative  $\dot{P} \sim 2 \times 10^{-12}$  s. Despite deep searches [77, 159], no evidence for orbital motion has been found, supporting the isolated neutron star scenario. Further observations [158, 78, 122] revealed a soft X-ray spectrum typical of an AXP, best fitted by an absorbed blackbody ( $kT \sim 0.4$  keV) plus a power-law

( $\Gamma \sim 3.7$ ). More recent Chandra [81, 121], XMM-Newton [52, 128] and Swift X-ray Telescope (XRT) [133] observations have shown that 4U 0142+614 is a relatively stable X-ray emitter (although recently it showed an outburst). In the last few years, two peculiar characteristics of 4U 0142+614 have been found in comparison with other AXPs: (i) an optical counterpart [65] displaying 8.7 s pulsation with a 30 per cent pulsed fraction [84] and (ii) mid-infrared emission, tentatively interpreted as the signature of a non-accreting disc around the neutron star [157]. Furthermore, like in other magnetars, a hard X-ray emission up to 250 keV has been revealed [18, 21].

### 5.3 1E 1048.1–5937

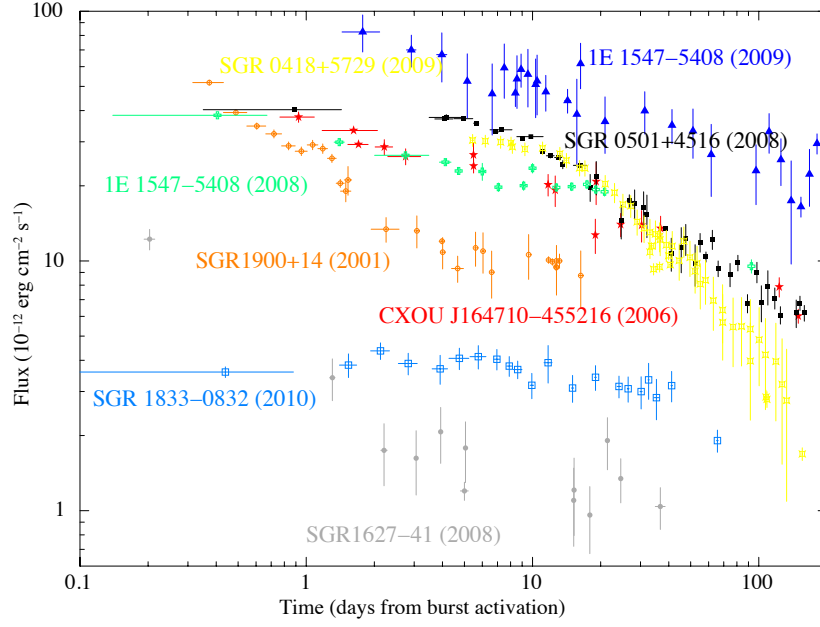
The 6.4 s X-ray pulsar 1E 1048.1–5937 was serendipitously discovered by Einstein during observations of the Carina Nebula [137]. Immediately suggested to be highly variable,<sup>1</sup> it was tentatively classified as a binary with a  $V \sim 19$  mag Be companion [137]. Subsequent observations however ruled out the candidate optical counterpart and 1E 1048.1–5937 was placed in the emerging (at the time) class of the anomalous X-ray pulsars [63, 152, 107]. During October/November 2001 a couple of SGR-like bursts – the firsts ever found in an AXP – were detected from 1E 1048.1–5937 with RXTE, virtually unifying the SGR and AXP classes [47].

1E 1048.1–5937 is one of the most frequently observed magnetars and in the last decade in particular it has been extensively monitored with RXTE since, because of its unstable spin down, frequent RXTE observations are necessary in following the spin evolution [46]. The long-term light curve of 1E 1048.1–5937 shows two consecutive outbursts in the 2002–2004, and another event in 2007 [138].

The late 2001 bursts marked the start of the first stretch of enhanced flux that persisted a few months [46]. The peak flux was  $\sim 2$  times the mean quiescent value ( $\approx 7 \times 10^{-12}$  erg cm<sup>-2</sup> s<sup>-1</sup>). Another larger (the peak flux reached  $\sim 3$  times the quiescent one) and longer-lived flux increase started in Spring 2002 and lasted into 2004. A third burst was observed from 1E 1048.1–5937 in June 2004, during the final phases of the outburst. Both events had a few-weeks-long rise time and much longer and gradual decays. These flux variations were accompanied by substantial timing irregularities (including glitches) which, however, do not correlate in an obvious way with the flux enhancements [46]. On the other hand, anti-correlation between pulsed fraction and flux and a correlation between spectral hardness and flux have been reported for this source [148, 138].

In March 2007 1E 1048.1–5937 entered a new outburst accompanied by a large spin-up glitch [22]. This time, the flux rose to the peak (slightly higher than that of the 2002–2004 outburst) in less than a week. Also a fourth burst was detected by RXTE about a month after the outburst onset [22]. For a distance of 9 kpc [25], the total energy emitted has been estimated in roughly  $4.8 \times 10^{41}$ ,  $3.5 \times 10^{42}$ , and  $4.3 \times$

<sup>1</sup> The flux variability of 1E 1048.1–5937 had been long debated and could be confirmed only twenty years later [109, 46].



**Fig. 3** Flux evolution over the first  $\sim 200$  days of recent magnetar outbursts (all observed with imaging instruments). Fluxes are reported in the 1–10 keV energy range, and the reported times are calculated in days from the detection of the first burst in each source. In particular we show CXOU J1647–4552 in red [76], SGR 1627–41 in grey [31], SGR 1806–20 in orange [39], 1E 1547–5408 in green and blue for the 2008 and 2009 outbursts, respectively [75, 116], SGR 0501+4516 in black [127], SGR 0418+5729 in yellow [37], and SGR 1833–0832 in light blue [50, 33].

$10^{42}$  erg for the three outbursts in chronological order [22]. We note that Gaensler et al. [43] propose an association between 1E 1048.1–5937 and the hydrogen shell GSH 288.3–0.5–28, which would pose the source at a much shorter distance of 2.7 kpc.

A candidate infrared counterpart to 1E 1048.1–5937 ( $K_s = 19.4$  mag) was selected in 2001 with the Baade (Magellan I) telescope [156] and confirmed by subsequent observations of large variability ( $\sim 2$  mag) [74, 24]. Changes in the infrared flux were initially suggested to be anti-correlated with those in the X-ray flux [24]. Recent observations however showed a behavior inconsistent with this hypothesis, with infrared flux enhancements near those at X-rays, indicating that neither disposition holds all the time [138, 155].

### 5.4 CXOU J1647–4552

CXOU J1647–4552 was discovered during deep X-ray observations of the massive star cluster Westerlund 1 [113]. In 2006 it underwent a large outburst [113, 114], preceded by a bright X-ray burst detected with the Swift observatory on 2006 September 21. This 10.6 s X-ray pulsar is located in the young cluster of massive stars, Westerlund 1 [113]. Several observations with multiple X-ray telescopes were performed following the burst detection, showing a the flux from this magnetar increased by a factor of  $\sim 100$  following the outburst. XMM-Newton observed the source just 4 days prior to the outburst, providing one of the few cases where the beginning of the outburst could be assessed with relative precision. Munro et al. [114] showed that the spectrum of CXOU J1647–4552 hardened significantly when the flux increased and that the pulse profile changed dramatically from a simple near-sinusoidal shape to a complex profile with three distinct peaks per cycle. A glitch as large as  $\Delta\nu/\nu > 1.5 \times 10^{-5}$  was detected in coincidence with the outburst ([76] but see also [160]).

### 5.5 XTE J1810–197

It was only in 2003 that the first transient magnetar was discovered, namely XTE J1810–197, which displayed a factor of  $> 100$  persistent flux enhancement with respect to the unpulsed pre-outburst quiescent luminosity level ( $> 10^{33} \text{ erg s}^{-1}$ ; [68, 71, 54]). Unfortunately, the initial phases of the outburst were missed and we do not know whether a bursting activity phase occurred in coincidence with also for this source. During the latest 5 years it was extensively observed, covering a flux variability over a factor of about  $> 60$ . Since the very first 2003 observations of XTE J1810–197, carried out approximately one year after the onset of the outburst, it was evident [54] that the source spectral shape (initially of two blackbodies with  $kT = 0.29 \pm 0.03 \text{ keV}$  and  $kT = 0.70 \pm 0.02 \text{ keV}$ ) was significantly different from that serendipitously recorded by ROSAT in 1992 (one blackbody with  $kT \sim 160 \text{ eV}$  [54]). Moreover, the source showed a 5.54 s pulsation with a pulsed fraction of nearly 45% during outburst, while an upper limit of 24% was inferred from the ROSAT data.

In 2006 the source was discovered to be one of the most intense and polarized radio pulsar in our sky with single peak flux density reaching a few Jy [10]. This finding provided direct evidence that the radio pulsar emission can also be at work in magnetars, corroborating the analogy with the rotational powered pulsars. Furthermore, it strongly suggested that a better way to study these objects (when in a high state) is taking into account for the whole emission properties of the source from radio to the hard X-ray. Simultaneous X-ray and radio observations have been performed. These suggested that the X-ray and radio emitting regions are likely coincident (or superimposed), the X-rays likely coming from a larger area. Moreover, during all these campaigns large radio flux ( $\sim 50\%$ ) and pulse shape variations have

been detected which do not correlate with any change (at a few percent level) of the X-ray timing and/or spectral parameters (Israel et al. in preparation). This suggests that the X-ray emission likely originates deep in the crust (or more in general, the radio and X-ray mechanisms are not closely related).

A variable infrared counterpart have been discovered for this object [71, 129], although no clear correlation between the X-ray and infrared variability have been confirmed [142]. XTE J1810–197 is now close to its quiescent level, and showed the longest outburst decay ever observed in magnetars, with a consequent slow spectral softening over a timescale of about 5 years (see also Figure 4).

## 5.6 1E 1547–5408

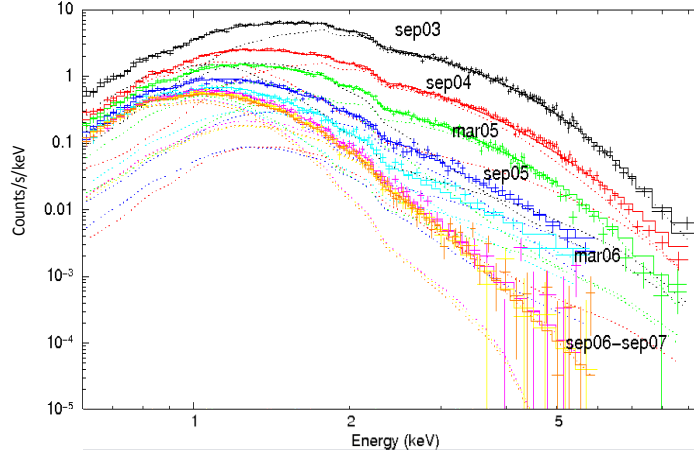
1E 1547–5408 was first proposed as a possible magnetar in the candidate supernova remnant G327.24–0.13 through X-ray observations [48] and subsequently recognized as a transient radio magnetar thanks to the discovery at radio frequencies of its spin period of  $\sim 2.1$  s [9] (later detected also in X-rays [62]). In recent years, 1E 1547–5408 has been one of the most active magnetars. A first outburst occurred during the Summer 2007, when Swift observations caught 1E 1547–5408 at an X-ray flux level of  $\sim 5 \times 10^{-12}$  erg cm $^{-2}$  s $^{-1}$ , more than one order of magnitude brighter than in quiescence [62]. However, the early phases of this outburst were missed and no bursts were observed (possibly due to a sparse X-ray coverage).

A new outburst started on 2008 October 3 [75, 116]. This time several bursts were detected by Swift and in the data taken immediately after the Swift trigger, 1E 1547–5408 was found at a flux level of  $\sim 6 \times 10^{-11}$  erg cm $^{-2}$  s $^{-1}$ . Then the luminosity declined by 70% in three weeks, following a power-law fading trend with decay index  $\sim -0.2$  [75]. During this period, the source displayed a complex timing and spectral variability [75, 116].

No further bursts were reported until 2009 January 22, when the source entered a new stretch of much stronger activity, with thousands of bright bursts detected by many instruments [106, 82, 136, 116]. A spectacular event connected with this giant outburst was the appearance around the source of multiple expanding X-ray rings due to scattering by different layers of interstellar dust of a particularly bright burst [149]. From the analysis of these structures, a distance to the source of  $\sim 4$  kpc was proposed [149].<sup>2</sup> Pulsations were detected up to  $\sim 150$  keV [88, 82], and the source reached a flux level of  $\sim 8 \times 10^{-11}$  erg cm $^{-2}$  s $^{-1}$  (see Figure 3). The (ongoing) intensive X-ray monitoring of 1E 1547–5408 shows that the flux is slowly decaying with an overall power-law trend with index  $\sim -0.3$ .

As periods of outburst activity are the most promising to search for radio and optical/infrared emission from magnetars, the 2009 outburst of 1E 1547–5408 triggered several multi-wavelength follow ups. Multiple radio observations were carried out at Parkes on 2009 January 22, 23 and 25. Pulsed emission from 1E 1547–

<sup>2</sup> This value agrees with the distance suggested by the possible association of 1E 1547–5408 with the supernova remnant G327.24–0.13 [48].



**Fig. 4** Spectral evolution of XTE J1810–197 over several years [1].

5408 was detected at 3 GHz during a 1.2-hour-long observation on January 25, but, notably, not in the other two occasions [5]. Moreover, a relatively bright transient (near) infrared source ( $K_s \sim 18.5$  mag) was discovered with ESO/VLT within the radio positional uncertainty of the AXP and identified with its counterpart [80]. Deep infrared observations taken with ESO/VLT during the 2007 outburst revealed four objects consistent with the radio position of 1E 1547–5408 [111]; none of them, however, showed variability and the likely counterpart was not detectable at the time. This sets an upper limit of about 21 mag in the  $K_s$  band on the infrared emission of the AXP during the 2007 outburst.

### 5.7 SGR 1806–20

SGR 1806–20 is arguably the most burst-prolific magnetar and showed several periods of bursting activity since the time of its discovery in 1979 [93, 94]. Its persistent X-ray counterpart was observed for the first time with the ASCA satellite in 1993 [115]. Subsequent observations with RXTE led to the discovery of coherent pulsations (the first time in an SGR) at  $P \simeq 7.5$  s and a secular increase of the period at a rate of  $\sim 8 \times 10^{-11}$  s s $^{-1}$  [86]. These values confirmed the debated neutron star nature of the SGRs and, since under the assumption of pure magnetic dipole braking they imply a surface magnetic field strength of  $8 \times 10^{14}$  G, provided strong support for the magnetar model, that was developed in the early 1990s [23, 119].

The source luminosity remained fairly constant for many years at  $\sim 5 \times 10^{35}$  erg s $^{-1}$  (for a distance of 15 kpc [15, 100]), until both the burst rate and the X-ray persis-

tent emission started increasing during 2003 and throughout 2004, when the luminosity approximately doubled with respect to the “historical” level [108, 162]. This period of intense activity culminated with a giant flare recorded on 2004 December 27 [67, 105, 120]. This giant flare was exceptionally intense (assuming isotropic luminosity  $\sim 10^{47}$  erg were released) and produced strong disturbances in the Earth’s ionosphere [12, 69] and detectable effects on the geomagnetic field [98].

The initial flash was followed by a tail clearly modulated at the spin frequency of SGR 1806–20 that persisted for  $\sim 380$  s. Comparing this giant flare with those seen from SGR 0526–66 and SGR 1900+14, it is found that the energy in the pulsating tails of the three events was roughly of the same order ( $\sim 10^{44}$  erg), while the energy in the initial spike of SGR 1806–20 (a few  $10^{46}$  erg) was at least two orders of magnitude higher than that of the other events.

Observations with RXTE unveiled, for the first time in an isolated neutron star, rapid quasi-periodic oscillations in the pulsating tail of the flare, likely related to global seismic oscillations on the neutron star surface [72]. The flare was accompanied by the emission of relativistic particles which powered a synchrotron nebula (a “mini-plerion”) that faded in a few months [7, 42, 141, 38]. A similar “radio afterglow” was observed also following the giant flare from SGR 1900+14 [40] (in the case of the 1979 event from SGR 0526–66, no data at radio wavelengths were available).

The small positional uncertainty of the radio observations permitted the identification of the infrared counterpart of the SGR [85, 70]. The fluxes observed in the infrared and gamma energy bands show a variability correlated with that observed in the 2–10 keV energy range [102]. After the giant flare, the persistent X-ray flux of SGR 1806–20 started to decrease from its outburst level, and its X-ray spectrum to soften, but the source has remained moderately burst-active to date [132, 102, 147, 162, 36]. During the Spring 2006 the source recovered its pre-outburst luminosity [102] and about five years after the flare (on 2009 September 7–8) the value measured with XMM-Newton was  $\sim 3 \times 10^{35}$  erg s $^{-1}$ . A flux decrease have been observed also from its infrared counterpart [70, 126, 102].

## 5.8 SGR 1627–41

SGR 1627–41 was discovered in 1998, when about one hundred bursts in six weeks were observed by CGRO/BATSE and other high-energy instruments [163]. Soon after the discovery of the bursts, its soft X-ray counterpart was identified with BeppoSAX at a flux level of  $\sim 7 \times 10^{-12}$  erg cm $^{-2}$  s $^{-1}$  (unabsorbed, 2–10 keV), corresponding to a luminosity of  $\sim 10^{35}$  erg s $^{-1}$  for a distance to the source of 11 kpc [14]. In the following 10 years no further bursting activity was reported while various observations carried out with BeppoSAX, ASCA, Chandra, and XMM-Newton showed a spectral softening and a monotonic decrease in the luminosity, down to a level of  $\sim 10^{33}$  erg s $^{-1}$  [87, 103, 34].

The long-term fading of SGR 1627–41 was suddenly interrupted by its burst re-activation on 2008 May 28, when several bursts were detected by the Swift/BAT during a short period of activity (about one day) [34]. This episode was associated with an abrupt and temporary large enhancement of the persistent X-ray flux (a factor of about 100 above the last measurement, in February 2008 with XMM-Newton) and a marked spectral hardening [34]. In September 2008, a deep XMM-Newton observation yielded the first measure of the spin period of the source (2.6 s, making SGR 1627–41 the second fastest spinning magnetar after 1E 1547–5408) and, together with searches in Chandra archival data, of its spin-down rate ( $1.9 \times 10^{-11} \text{ s s}^{-1}$ ) [37, 30]. In fact, while the detection of strong SGR-like bursts from SGR 1627–41 made it a bona fide member of the SGR class, these two strong pieces of evidence in favor of the identification were still missing.

Follow-up observations at near infrared and radio wavelengths were carried out in response to the 2008 burst activation, but they failed to detect the source [17, 11]. In particular, the limit on the radio pulsed emission of SGR 1627–41 at 1.4 GHz obtained at Parkes on 2008 May 30 and June 1 was 0.5 mJy (for a sinusoidal pulse profile) [11].

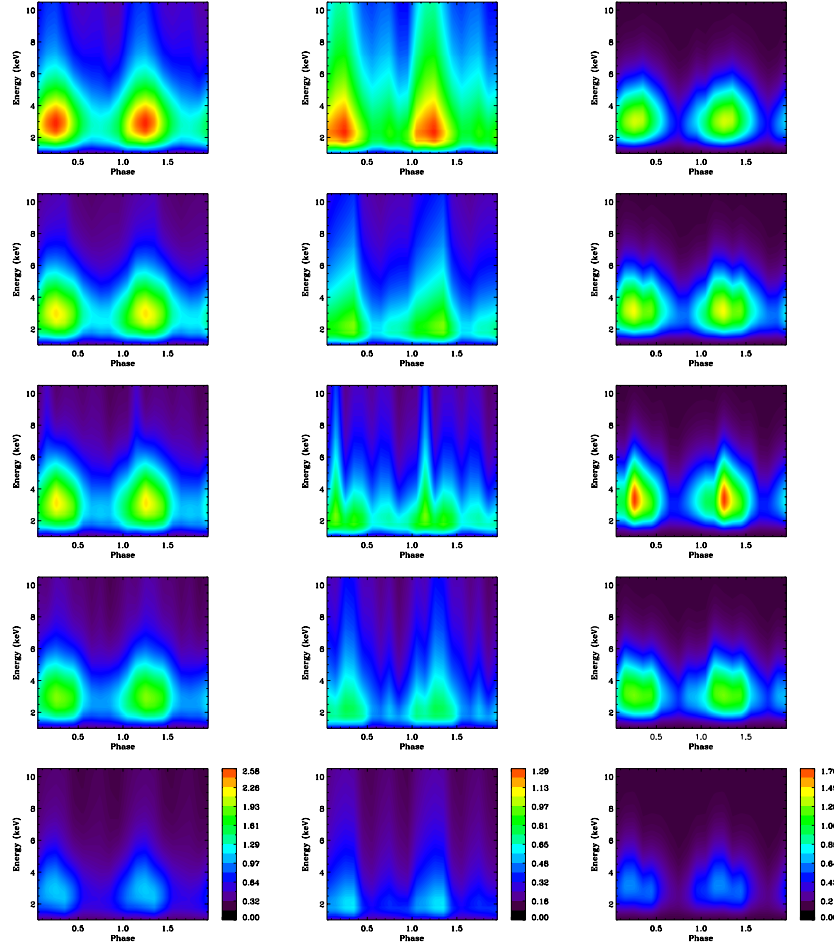
## 5.9 SGR 0501+4516

A new magnetar candidate, SGR 0501+4516 was discovered on 2008 August 22 by the Swift Burst Alert Telescope (BAT), thanks to the detection of SGR-like bursts. Tens of bursts were observed [106, 26, 127, 50] with fluxes exceeding the underlying continuum by a factor  $>10^5$ . The bursts reached a maximum luminosity of  $\sim 10^{41} \text{ erg s}^{-1}$  and had a durations of  $<1 \text{ s}$ , typical of those usually emitted by SGRs. Thanks to the rapid response of many X-ray satellites (Swift, Suzaku, XMM-Newton, Chandra, INTEGRAL, Fermi-GBM, AGILE) the source was repeatedly observed during and after its “burst forest” emission, leading to the best monitoring of an SGR outburst ever performed.

Archival ROSAT data dated September 1992 showed a faint unpulsed X-ray source consistent with the position of this new SGR, most probably its quiescent X-ray counterpart [127], at a flux level of  $\sim 10^{-12} \text{ erg s}^{-1} \text{ cm}^{-2}$ , and with a thermal spectrum well modeled by a blackbody with a temperature of  $kT \sim 0.3 \text{ keV}$  (although a power-law fit is also consistent with the data).

Since the very first XMM-Newton observation of SGR 0501+4516, carried out one day after the source bursting activation, it was already clear that the source spectral and timing properties changed enormously with respect to the ROSAT quiescent level, with a flux increase of almost 2 orders of magnitude and a much harder spectrum. The source characteristics evolved rapidly during the outburst decay showing a significant spectral softening in the first month of monitoring correlated with the flux decay [127]. The source rotate at  $\sim 5.7 \text{ s}$ , and a period derivative of  $\dot{P} = 6.8 \times 10^{-12} \text{ s s}^{-1}$ . Its pulse profile is highly variable (in time and as a function of energy), and it has a quite stable pulsed fraction of  $\sim 40\%$ ,





**Fig. 5** Dynamic Spectral Profiles (DSPs). Each row corresponds to one XMM-Newton observation (epoch increases from top to bottom: 2008 August 23, 29, 31, September 02 and 30) of SGR 0501+4516 [127]. The three columns represent in the phase/energy plane the contour plots for the total (left), power-law (middle) and blackbody (right)  $vF_v$  flux. The color scale is in units of  $0.01 \text{ keV}(\text{keV cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1})$ .

Given the good monitoring of this outbursts, a phase resolved decay has been observed for the first time. We show this in Figure 5. This clearly shows how different is the outburst evolution in phase, as well as the different decays of the thermal (much slower) and non-thermal (much faster) components.

### 5.10 SGR 0418+5729

SGR 0418+5729 was discovered due to its bursting activity in 2009 June 5 [151] and then its post-outburst behaviour was intensively monitored for about 160 days [32]. Only three bursts were detected from this SGR (all on 2009 June 5 [151]) and archival searches could not reveal any previous period of intense activity [151]; no new bursts have been detected until now. SGR 0418+5729 has a spin period of 9.1 s and its period derivative has so far eluded all measurements during its outburst decay.

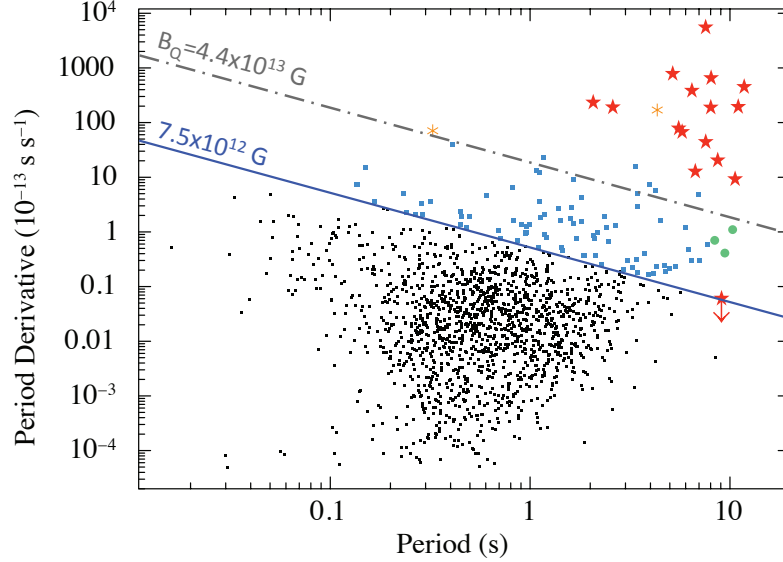
After the outburst onset, the source spectrum gradually softened and the persistent X-ray emission faded by a factor of  $\sim 10$  in about 160 days following a broken-power-law decay, with a steepening about 19 days after the activation, when the index changed from  $-0.3$  to  $-1.2$  [32]. At the same time, the complex and energy-variable pulse profile of the source showed a substantial evolution, pointing to a nearly orthogonal rotator seen at a large inclination angle and to the presence of two emitting caps, one of which became hotter during the outburst [32].

The most intriguing characteristic of this object comes from the current non-detection of its period derivative after  $\sim 500$  days from the outburst onset. In particular, the 90% limit on it is  $< 6 \times 10^{-15}$  s/s, leading to an upper limit on its magnetic field of  $B < 7.5 \times 10^{12}$  Gauss: an incredibly low magnetic field for an SGR [125]. This source shows that the magnetar population may thus include objects with a wider range of B-field strengths, ages and evolutionary stages than observed so far (see also Figure 6 and [125, 124]).

### 5.11 SGR 1833–0832

This recent addition to the magnetar family was discovered on 2010 March 19, when the Swift triggered on a short hard X-ray burst and localized it in a region close to the Galactic plane [50]. Swift immediately slewed to the BAT field and unveiled the existence of a previously unknown bright X-ray source. Given the proximity to the Galactic plane and the burst properties, the X-ray source was immediately suggested to be an SGR. Its SGR/magnetar nature has been confirmed shortly after by the discovery with Swift and RXTE of pulsations at 7.57 s and the measure of a period derivative of a few  $10^{-12}$  s/s [50, 33].

Follow-up observations could not reveal SGR 1833–0832 in the optical, infrared, and radio wavebands [50, 33]. The source was monitored in the X-rays with various instruments for about five months [50, 33], during which it displayed a low bursting activity, while the persistent flux decreased from  $\sim 4 \times 10^{-12}$  erg cm $^{-2}$  s $^{-1}$  by a factor of about four with an approximately exponential decay with a time scale ( $e$ -folding time) of  $\sim 110$  days [33]. Somewhat atypically, the spectrum of this source is well described by an absorbed single hot blackbody ( $kT \sim 1.2$  keV). However, the high absorbing column towards the source makes it difficult to properly model its emission and an additional spectral component cannot be excluded [33].



**Fig. 6** Diagram of the  $P-\dot{P}$  of all isolated pulsars known to date. Black squares represent normal radio pulsars, light-blue squares normal radio pulsars with a magnetic field larger than  $7.5 \times 10^{12}$  Gauss (our limit for SGR 0418+5729), red stars are the magnetars, orange asterisks are the magnetar-like pulsars PSR J1846–0258 and PSR 1622–4950, and the green circles are the X-ray Dim Isolated Neutron Stars (XDINSs). The blue solid line marks the 90% upper limit for the dipolar magnetic field of SGR 0418+5729. The value of the electron quantum magnetic field is also reported (dash-dotted grey line). See [125] for more info.

### 5.12 AX J1844–0258

This source was discovered in a 1993 observation of the (not associated) supernova remnant Kes 75 during a search for pulsating sources [150, 55]. The observed flux was  $\sim 4 \times 10^{-12}$  erg cm $^{-2}$  s $^{-1}$ . The long period (7 s) together with the spectral properties and the lack of a companion suggested that AX J1844–0258 is an AXP. The source was observed again with ASCA in 1997 and 1999 and revealed only in the 1999 observation, at a ten times lower flux (which is consistent with the marginal 1997 non detection) [153]. Subsequent BeppoSAX, Chandra, and XMM-Newton observations revealed an X-ray source at a flux level similar to that observed from AX J1845.0–0258 in 1999 [71, 139]. The low flux precluded new measurements of pulsations and therefore there is no information about the rate of change of the spin period (for this reason the source is often indicated as a candidate AXP).

If AX J1844–0258 is indeed an AXP, it is plausible that like other magnetars it has a transient behavior and that the 1993 ASCA observation was carried out during (or shortly after) an outburst. Moreover, Tam et al. [139] noticed that, given the large

uncertainty on the ASCA position, it is not ruled out that the X-ray source observed by the other satellites is a field-source unrelated to the 7-s pulsar AX J1844–0258. If so, the upper limit on the flux that they obtained from a deep Chandra observation of the field would point to a flux decrease of a factor of 200 or more.

## 6 Conclusions

In this review we reported on all magnetar outbursts recorded to date (see also Figure 3). Although far from having an exhaustive understanding on the mechanism and observational behavior of magnetar outbursts (see [124] for a recent work in that direction), some common lines can be drawn. Before listing the few common properties as they appear up to know, we caveat that many bias might be in place. The most evident is that in several cases we have no information on the exact time of the outburst onset, hence the observations we are comparing for different sources might be relative to different times during the outburst decay.

- A clear softening of the X-ray spectrum during the outburst decay is observed in all cases. There is a large amount of higher energy photons emitted at the beginning of the outburst that fade during the flux decay toward quiescence. In some cases this was even connected to the detection of a transient hard X-ray emission days after the on-set of the outburst, which faded away very rapidly ( $\sim$  a week; see the case of SGR 0501+4516).
- There is a connection between the enhancement of the persistent emission and the source bursting activity, although the sparse observations does not allow to figure out whether there is a connection between the fluence of those outbursts and the amount or energetic of the short bursts.
- A single source can emit several outbursts (see e.g. the case of 1E 1547–5408), of different intensities and timescales.
- There is no clear understanding on the radio, infrared and optical emission during outbursts. In the radio band, in some cases radio pulsed emission were detected in connection to the X-ray enhancements (it is not clear yet who triggers who, though), in others not. On the other hand, infrared and optical emission were sometimes found to get enhanced by the X-ray outburst activity, while in other cases they were not.
- Large differences in the timescales and decay-laws are observed among different outbursts, even in the same source.

**Acknowledgements** NR acknowledges support from a Ramon y Cajal Fellowship and from grants AYA2009-07391 and SGR2009-811. PE acknowledges financial support from the Autonomous Region of Sardinia through a research grant under the program PO Sardegna FSE 2007–2013, L.R. 7/2007 “Promoting scientific research and innovation technology in Sardinia”.

## References

- [1] Albano, A., Turolla, R., Israel, G.L., Zane, S., Nobili, L., Stella, L.: A Unified Timing and Spectral Model for the Anomalous X-ray Pulsars XTE J1810-197 and CXOU J164710.2-455216. *ApJ* **722**, 788–802 (2010). DOI 10.1088/0004-637X/722/1/788
- [2] Baade, W., Zwicky, F.: Remarks on Super-Novae and Cosmic Rays. *Physical Review* **46**, 76–77 (1934). DOI 10.1103/PhysRev.46.76.2
- [3] Baring, M.G., Harding, A.K.: Resonant Compton upscattering in anomalous X-ray pulsars. *Ap&SS* **308**, 109–118 (2007). DOI 10.1007/s10509-007-9326-x
- [4] Beloborodov, A.M., Thompson, C.: Corona of Magnetars. *ApJ* **657**, 967–993 (2007). DOI 10.1086/508917
- [5] Burgay, M., Israel, G.L., Possenti, A., Rea, N., Esposito, P., Mereghetti, S., Tiengo, A., Götz, D.: Back to radio: Parkes detection of radio pulses from the transient AXP 1E1547.0-5408. *Astron. Tel.* **1913** (2009)
- [6] Burgay, M., Rea, N., Israel, G.L., Possenti, A., Burderi, L., di Salvo, T., D’Amico, N., Stella, L.: Search for radio pulsations in four Anomalous X-ray Pulsars and discovery of two new pulsars. *MNRAS* **372**, 410–416 (2006). DOI 10.1111/j.1365-2966.2006.10872.x
- [7] Cameron, P.B., Chandra, P., Ray, A., Kulkarni, S.R., Frail, D.A., Wieringa, M.H., Nakar, E., Phinney, E.S., Miyazaki, A., Tsuboi, M., Okumura, S., Kawai, N., Menten, K.M., Bertoldi, F.: Detection of a radio counterpart to the 27 December 2004 giant flare from SGR 1806-20. *Nature* **434**, 1112–1115 (2005). DOI 10.1038/nature03605
- [8] Camilo, F., Cognard, I., Ransom, S.M., Halpern, J.P., Reynolds, J., Zimmerman, N., Gotthelf, E.V., Helfand, D.J., Demorest, P., Theureau, G., Backer, D.C.: The Magnetar XTE J1810-197: Variations in Torque, Radio Flux Density, and Pulse Profile Morphology. *ApJ* **663**, 497–504 (2007). DOI 10.1086/518226
- [9] Camilo, F., Ransom, S.M., Halpern, J.P., Reynolds, J.: 1E 1547.0-5408: A Radio-emitting Magnetar with a Rotation Period of 2 Seconds. *ApJ* **666**, L93–L96 (2007). DOI 10.1086/521826
- [10] Camilo, F., Ransom, S.M., Halpern, J.P., Reynolds, J., Helfand, D.J., Zimmerman, N., Sarkissian, J.: Transient pulsed radio emission from a magnetar. *Nature* **442**, 892–895 (2006). DOI 10.1038/nature04986
- [11] Camilo, F., Sarkissian, J.: No radio pulsations detected from SGR 1627-41 following renewed X-ray activity. *Astron. Tel.* **1558** (2008)
- [12] Campbell, P., Hill, M., Howe, R., Kielkopf, J.F., Lewis, N., Mandaville, J., McWilliams, A., Moos, W., Samouce, D., Winkler, J., Fishman, G.J., Price, A., Welch, D.L., Schnoor, P., Clerkin, A., Saum, D.: SGR 1806-20: detection of a sudden ionospheric disturbance. *GRB Circular Network* **2932** (2005)
- [13] Chandrasekhar, S.: The Maximum Mass of Ideal White Dwarfs. *ApJ* **74**, 81 (1931). DOI 10.1086/143324

- [14] Corbel, S., Chapuis, C., Dame, T.M., Durouchoux, P.: The Distance to the Soft Gamma Repeater SGR 1627-41. *ApJ* **526**, L29–L32 (1999)
- [15] Corbel, S., Wallyn, P., Dame, T.M., Durouchoux, P., Mahoney, W.A., Vilhu, O., Grindlay, J.E.: The Distance of the Soft Gamma Repeater SGR 1806-20. *ApJ* **478**, 624 (1997)
- [16] Crawford, F., Hessels, J.W.T., Kaspi, V.M.: Deep Searches for Radio Pulsations and Bursts from Four Southern Anomalous X-Ray Pulsars. *ApJ* **662**, 1183–1187 (2007). DOI 10.1086/517991
- [17] de Ugarte Postigo, A., Castro-Tirado, A.J., Covino, S., Gorosabel, J., D’Avanzo, P., Nürnberger, D.E.A.: Near-infrared follow-up to the May 2008 activation of SGR 1627-41. *A&A* **500**, 1157–1161 (2009). DOI 10.1051/0004-6361/200811384
- [18] den Hartog, P.R., Hermsen, W., Kuiper, L., Vink, J., in’t Zand, J.J.M., Collmar, W.: INTEGRAL survey of the Cassiopeia region in hard X rays. *A&A* **451**, 587–602 (2006). DOI 10.1051/0004-6361:20054711
- [19] den Hartog, P.R., Kuiper, L., Hermsen, W.: Detailed high-energy characteristics of AXP 1RXS J170849-400910. Probing the magnetosphere using INTEGRAL, RXTE, and XMM-Newton. *A&A* **489**, 263–279 (2008). DOI 10.1051/0004-6361:200809772
- [20] den Hartog, P.R., Kuiper, L., Hermsen, W., Kaspi, V.M., Dib, R., Knödseder, J., Gavriil, F.P.: Detailed high-energy characteristics of AXP 4U 0142+61. Multi-year observations with INTEGRAL, RXTE, XMM-Newton, and ASCA. *A&A* **489**, 245–261 (2008). DOI 10.1051/0004-6361:200809390
- [21] den Hartog, P.R., Kuiper, L., Hermsen, W., Rea, N., Durant, M., Stappers, B., Kaspi, V.M., Dib, R.: The first multi-wavelength campaign of AXP 4U 0142+61 from radio to hard X-rays. *Ap&SS* **308**, 647–653 (2007). DOI 10.1007/s10509-007-9367-1
- [22] Dib, R., Kaspi, V.M., Gavriil, F.P.: Rossi X-Ray Timing Explorer Monitoring of the Anomalous X-ray Pulsar 1E 1048.1-5937: Long-term Variability and the 2007 March Event. *ApJ* **702**, 614–630 (2009). DOI 10.1088/0004-637X/702/1/614
- [23] Duncan, R.C., Thompson, C.: Formation of very strongly magnetized neutron stars - Implications for gamma-ray bursts. *ApJ* **392**, L9–L13 (1992)
- [24] Durant, M., van Kerkwijk, M.H.: The Broadband Spectrum and Infrared Variability of the Magnetar AXP 1E 1048.1-5937. *ApJ* **627**, 376–382 (2005). DOI 10.1086/429714
- [25] Durant, M., van Kerkwijk, M.H.: Distances to Anomalous X-Ray Pulsars Using Red Clump Stars. *ApJ* **650**, 1070–1081 (2006). DOI 10.1086/506380
- [26] Enoto, T., Nakagawa, Y.E., Rea, N., Esposito, P., Götz, D., Hurley, K., Israel, G.L., Kokubun, M., Makishima, K., Mereghetti, S., Murakami, H., Nakazawa, K., Sakamoto, T., Stella, L., Tiengo, A., Turolla, R., Yamada, S., Yamaoka, K., Yoshida, A., Zane, S.: Suzaku Observation of the New Soft Gamma Repeater SGR 0501+4516 in Outburst. *ApJ* **693**, L122–L126 (2009). DOI 10.1088/0004-637X/693/2/L122

- [27] Enoto, T., Nakazawa, K., Makishima, K., Nakagawa, Y.E., Sakamoto, T., Ohno, M., Takahashi, T., Terada, Y., Yamaoka, K., Murakami, T., Takahashi, H.: Suzaku Discovery of a Hard X-Ray Tail in the Persistent Spectra from the Magnetar 1E 1547.0-5408 during its 2009 Activity. *PASJ* **62**, 475 (2010)
- [28] Enoto, T., Nakazawa, K., Makishima, K., Rea, N., Hurley, K., Shibata, S.: Broadband Study with Suzaku of the Magnetar Class. *ApJ* **722**, L162–L167 (2010). DOI 10.1088/2041-8205/722/2/L162
- [29] Ertan, Ü., Cheng, K.S.: On the Infrared, Optical, and High-Energy Emission from the Anomalous X-Ray Pulsar 4U 0142+61. *ApJ* **605**, 840–845 (2004). DOI 10.1086/382502
- [30] Esposito, P., Burgay, M., Possenti, A., Turolla, R., Zane, S., De Luca, A., Tiengo, A., Israel, G.L., Mattana, F., Mereghetti, S., Bailes, M., Romano, P., Götz, D., Rea, N.: Spin-down rate and inferred dipole magnetic field of the soft gamma-ray repeater SGR 1627-41. *MNRAS* **399**, L44–L48 (2009). DOI 10.1111/j.1745-3933.2009.00723.x
- [31] Esposito, P., Israel, G. L., Zane, S., Senziani, F., Starling, R. L. C., Rea, N., Palmer, D. M., Gehrels, N., Tiengo, A., de Luca, A., Götz, D., Mereghetti, S., Romano, P., Sakamoto, T., Barthelmy, S. D., Stella, L., Turolla, R., Feroci, M., Mangano, V.: The 2008 May burst activation of SGR1627-41. *MNRAS* **390**, L34–L38 (2008). DOI 10.1111/j.1745-3933.2008.00530.x
- [32] Esposito, P., Israel, G.L., Turolla, R., Tiengo, A., Götz, D., De Luca, A., Mignani, R.P., Zane, S., Rea, N., Testa, V., Caraveo, P.A., Chaty, S., Mattana, F., Mereghetti, S., Pellizzoni, A., Romano, P.: Early X-ray and optical observations of the soft gamma-ray repeater SGR 0418+5729. *MNRAS* **405**, 1787–1795 (2010). DOI 10.1111/j.1365-2966.2010.16551.x
- [33] Esposito, P., Israel, G.L., Turolla, R., Tiengo, A., Possenti, A., Rea, N., Burgay, M., Mereghetti, S., Stella, L., Zane, S., Götz, D., Wieringa, M.H., Sarkissian, J.M., Mattana, F., Enoto, T., Sakamoto, T., Nakagawa, Y.E., Makishima K. and Nakazawa, K., Sarkissian, K., Nishioka, H., François-Martin, C.: The new soft gamma-ray repeater SGR 1833-0832: X-ray and radio observations. in preparation (2011)
- [34] Esposito, P., Israel, G.L., Zane, S., Senziani, F., Starling, R.L.C., Rea, N., Palmer, D.M., Gehrels, N., Tiengo, A., De Luca, A., Götz, D., Mereghetti, S., Romano, P., Sakamoto, T., Barthelmy, S.D., Stella, L., Turolla, R., Feroci, M., Mangano, V.: The 2008 May burst activation of SGR 1627-41. *MNRAS* **390**, L34–L38 (2008). DOI 10.1111/j.1745-3933.2008.00530.x
- [35] Esposito, P., Mereghetti, S., Tiengo, A., Sidoli, L., Feroci, M., Woods, P.: Five years of SGR 1900+14 observations with BeppoSAX. *A&A* **461**, 605–612 (2007). DOI 10.1051/0004-6361:20065529
- [36] Esposito, P., Mereghetti, S., Tiengo, A., Zane, S., Turolla, R., Götz, D., Rea, N., Kawai, N., Ueno, M., Israel, G.L., Stella, L., Feroci, M.: SGR 1806-20 about two years after the giant flare: Suzaku, XMM-Newton and INTEGRAL observations. *A&A* **476**, 321–330 (2007). DOI 10.1051/0004-6361:20078562

- [37] Esposito, P., Tiengo, A., Mereghetti, S., Israel, G.L., De Luca, A., Götz, D., Rea, N., Turolla, R., Zane, S.: XMM-Newton Discovery of 2.6 s Pulsations in the Soft Gamma-Ray Repeater SGR 1627-41. *ApJ* **690**, L105–L109 (2009). DOI 10.1088/0004-637X/690/2/L105
- [38] Fender, R.P., Muxlow, T.W.B., Garrett, M.A., Kouveliotou, C., Gaensler, B.M., Garrington, S.T., Paragi, Z., Tudose, V., Miller-Jones, J.C.A., Spencer, R.E., Wijers, R.A.M., Taylor, G.B.: Structure in the radio counterpart to the 2004 December 27 giant flare from SGR 1806-20. *MNRAS* **367**, L6–L10 (2006). DOI 10.1111/j.1745-3933.2006.00123.x
- [39] Feroci, M., Hurley, K., Duncan, R.C., Thompson, C.: The Giant Flare of 1998 August 27 from SGR 1900+14. I. An Interpretive Study of BeppoSAX and Ulysses Observations. *ApJ* **549**, 1021–1038 (2001). DOI 10.1086/319441
- [40] Frail, D.A., Kulkarni, S.R., Bloom, J.S.: An outburst of relativistic particles from the soft gamma-ray repeater SGR 1900+14. *Nature* **398**, 127–129 (1999)
- [41] Frail, D.A., Vasisht, G., Kulkarni, S.R.: The Changing Structure of the Radio Nebula around the Soft Gamma-Ray Repeater SGR 1806-20. *ApJ* **480**, L129+ (1997). DOI 10.1086/310635
- [42] Gaensler, B.M., Kouveliotou, C., Gelfand, J.D., Taylor, G.B., Eichler, D., Wijers, R.A.M.J., Granot, J., Ramirez-Ruiz, E., Lyubarsky, Y.E., Hunstead, R.W., Campbell-Wilson, D., van der Horst, A.J., McLaughlin, M.A., Fender, R.P., Garrett, M.A., Newton-McGee, K.J., Palmer, D.M., Gehrels, N., Woods, P.M.: An expanding radio nebula produced by a giant flare from the magnetar SGR 1806-20. *Nature* **434**, 1104–1106 (2005). DOI 10.1038/nature03498
- [43] Gaensler, B.M., McClure-Griffiths, N.M., Oey, M.S., Haverkorn, M., Dickey, J.M., Green, A.J.: A Stellar Wind Bubble Coincident with the Anomalous X-Ray Pulsar 1E 1048.1-5937: Are Magnetars Formed from Massive Progenitors? *ApJ* **620**, L95–L98 (2005). DOI 10.1086/428725
- [44] Gaensler, B.M., Slane, P.O., Gotthelf, E.V., Vasisht, G.: Anomalous X-Ray Pulsars and Soft Gamma-Ray Repeaters in Supernova Remnants. *ApJ* **559**, 963–972 (2001)
- [45] Gavriil, F.P., Gonzalez, M.E., Gotthelf, E.V., Kaspi, V.M., Livingstone, M.A., Woods, P.M.: Magnetar-Like Emission from the Young Pulsar in Kes 75. *Science* **319**, 1802–1805 (2008). DOI 10.1126/science.1153465
- [46] Gavriil, F.P., Kaspi, V.M.: Anomalous X-Ray Pulsar 1E 1048.1-5937: Pulsed Flux Flares and Large Torque Variations. *ApJ* **609**, L67–L70 (2004). DOI 10.1086/422751
- [47] Gavriil, F.P., Kaspi, V.M., Woods, P.M.: Magnetar-like X-ray bursts from an anomalous X-ray pulsar. *Nature* **419**, 142–144 (2002)
- [48] Gelfand, J.D., Gaensler, B.M.: The Compact X-Ray Source 1E 1547.0-5408 and the Radio Shell G327.24-0.13: A New Proposed Association between a Candidate Magnetar and a Candidate Supernova Remnant. *ApJ* **667**, 1111–1118 (2007). DOI 10.1086/520526
- [49] Gelfand, J.D., Lyubarsky, Y.E., Eichler, D., Gaensler, B.M., Taylor, G.B., Granot, J., Newton-McGee, K.J., Ramirez-Ruiz, E., Kouveliotou, C., Wijers,



- R.A.M.J.: A Rebrightening of the Radio Nebula Associated with the 2004 December 27 Giant Flare from SGR 1806-20. *ApJ* **634**, L89–L92 (2005). DOI 10.1086/498643
- [50] Göğüş, E., Cusumano, G., Levan, A.J., Kouveliotou, C., Sakamoto, T., Barthelmy, S.D., Campana, S., Kaneko, Y., Stappers, B.W., de Ugarte-Postigo, A., Strohmayer, T., Palmer, D.M., Gelbord, J., Burrows, D.N., van der Horst, A.J., Munoz-Darias, T., Gehrels, N., Hessels, J.W.T., Kamble, A.P., Wachter, S., Wiersema, K., Wijers, R.A.M.J., Woods, P.M.: Discovery of a new Soft Gamma Repeater, SGR J1833-0832. *ApJ* **718**, 331–339 (2010)
- [51] Göğüş, E., Guver, T., Ozel, F., Eichler, D., Kouveliotou, C.: Long Term Radiative Behavior of SGR 1900+14. *ApJ*, in press (preprint: astro-ph/1101.1450) (2011)
- [52] Göhler, E., Wilms, J., Staubert, R.: XMM-Newton observation of the anomalous X-ray pulsar 4U 0142+61. *A&A* **433**, 1079–1083 (2005). DOI 10.1051/0004-6361:20042101
- [53] Gotthelf, E.V., Halpern, J.P.: The Spectral Evolution of Transient Anomalous X-Ray Pulsar XTE J1810-197. *ApJ* **632**, 1075–1085 (2005). DOI 10.1086/432709
- [54] Gotthelf, E.V., Halpern, J.P., Buxton, M., Bailyn, C.: Imaging X-Ray, Optical, and Infrared Observations of the Transient Anomalous X-Ray Pulsar XTE J1810-197. *ApJ* **605**, 368–377 (2004). DOI 10.1086/382232
- [55] Gotthelf, E.V., Vasisht, G.: Discovery of a 7 second anomalous X-ray pulsar in the distant Milky Way. *New Astronomy* **3**, 293–300 (1998). DOI 10.1016/S1384-1076(98)00014-1
- [56] Götz, D., Mereghetti, S., Hurley, K.: Unveiling soft gamma-ray repeaters with INTEGRAL. *Ap&SS* **308**, 51–59 (2007). DOI 10.1007/s10509-007-9379-x
- [57] Götz, D., Mereghetti, S., Tiengo, A., Esposito, P.: Magnetars as persistent hard X-ray sources: INTEGRAL discovery of a hard tail in SGR 1900+14. *A&A* **449**, L31–L34 (2006). DOI 10.1051/0004-6361:20064870
- [58] Götz, D., Rea, N., Israel, G.L., Zane, S., Esposito, P., Gotthelf, E.V., Mereghetti, S., Tiengo, A., Turolla, R.: Long term hard X-ray variability of the anomalous X-ray pulsar 1RXS J170849.0-400910 discovered with INTEGRAL. *A&A* **475**, 317–321 (2007). DOI 10.1051/0004-6361:20078291
- [59] Güver, T., Özel, F., Göğüş, E.: Physical Properties of the AXP 4U 0142+61 from X-Ray Spectral Analysis. *ApJ* **675**, 1499–1504 (2008). DOI 10.1086/525840
- [60] Halpern, J.P., Gotthelf, E.V.: The Fading of Transient Anomalous X-Ray Pulsar XTE J1810-197. *ApJ* **618**, 874–882 (2005). DOI 10.1086/426130
- [61] Halpern, J.P., Gotthelf, E.V.: An Energetic Magnetar in HESS J1713-381/CTB 37B. *ApJ* **725**, 1384–1391 (2010). DOI 10.1088/0004-637X/725/1/1384
- [62] Halpern, J.P., Gotthelf, E.V., Reynolds, J., Ransom, S.M., Camilo, F.: Outburst of the 2 s Anomalous X-Ray Pulsar 1E 1547.0-5408. *ApJ* **676**, 1178–1183 (2008). DOI 10.1086/527293

- [63] Hellier, C.: A ROSAT observation of the X-ray pulsars X0142+614 and X0146+612. *MNRAS* **271**, L21–L24 (1994)
- [64] Hewish, A., Bell, S.J., Pilkington, J.D.H., Scott, P.F., Collins, R.A.: Observation of a Rapidly Pulsating Radio Source. *Nature* **217**, 709–713 (1968). DOI 10.1038/217709a0
- [65] Hulleman, F., van Kerkwijk, M.H., Kulkarni, S.R.: An optical counterpart to the anomalous X-ray pulsar 4U0142+61. *Nature* **408**, 689–692 (2000)
- [66] Hulleman, F., van Kerkwijk, M.H., Kulkarni, S.R.: The Anomalous X-ray Pulsar 4U 0142+61: Variability in the infrared and a spectral break in the optical. *A&A* **416**, 1037–1045 (2004). DOI 10.1051/0004-6361:20031756
- [67] Hurley, K., Boggs, S.E., Smith, D.M., Duncan, R.C., Lin, R., Zoglauer, A., Krucker, S., Hurford, G., Hudson, H., Wigger, C., Hajdas, W., Thompson, C., Mitrofanov, I., Sanin, A., Boynton, W., Fellows, C., von Kienlin, A., Lichti, G., Rau, A., Cline, T.: An exceptionally bright flare from SGR 1806-20 and the origins of short-duration  $\gamma$ -ray bursts. *Nature* **434**, 1098–1103 (2005). DOI 10.1038/nature03519
- [68] Ibrahim, A.I., Markwardt, C.B., Swank, J.H., Ransom, S., Roberts, M., Kaspi, V., Woods, P.M., Safi-Harb, S., Balman, S., Parke, W.C., Kouveliotou, C., Hurley, K., Cline, T.: Discovery of a Transient Magnetar: XTE J1810-197. *ApJ* **609**, L21–L24 (2004). DOI 10.1086/422636
- [69] Inan, U.S., Lehtinen, N.G., Moore, R., Hurley, K., Boggs, S., Smith, D.M., Fishman, G.J.: Massive disturbance of the daytime lower ionosphere by the giant  $\gamma$ -ray flare from magnetar sgr 1806-20. *Geophysical Research Letters* **34**, 8103 (2007). DOI 10.1029/2006GL029145
- [70] Israel, G., Covino, S., Mignani, R., Stella, L., Marconi, G., Testa, V., Mereghetti, S., Campana, S., Rea, N., Götz, D., Perna, R., Lo Curto, G.: Discovery and monitoring of the likely IR counterpart of SGR 1806-20 during the 2004  $\gamma$ -ray burst-active state. *A&A* **438**, L1–L4 (2005). DOI 10.1051/0004-6361:200500138
- [71] Israel, G., Stella, L., Covino, S., Campana, S., Angelini, L., Mignani, R., Mereghetti, S., Marconi, G., Perna, R.: Unveiling the Multi-wavelength Phenomenology of Anomalous X-ray Pulsars. In: *IAU Symposium no. 218, Young Neutron Stars and Their Environments*. Ed. by F. Camilo and B. M. Gaensler. San Francisco, CA: Astronomical Society of the Pacific, p. 247 (2004)
- [72] Israel, G.L., Belloni, T., Stella, L., Rephaeli, Y., Gruber, D.E., Casella, P., Dall’Osso, S., Rea, N., Persic, M., Rothschild, R.E.: The Discovery of Rapid X-Ray Oscillations in the Tail of the SGR 1806-20 Hyperflare. *ApJ* **628**, L53–L56 (2005). DOI 10.1086/432615
- [73] Israel, G.L., Campana, S., Dall’Osso, S., Muno, M.P., Cummings, J., Perna, R., Stella, L.: The Post-Burst Awakening of the Anomalous X-Ray Pulsar in Westerlund 1. *ApJ* **664**, 448–457 (2007). DOI 10.1086/518224
- [74] Israel, G.L., Covino, S., Stella, L., Campana, S., Marconi, G., Mereghetti, S., Mignani, R., Negueruela, I., Oosterbroek, T., Parmar, A.N., Burderi, L., Angelini, L.: The Detection of Variability from the Candidate Infrared Counter-

- part to the Anomalous X-Ray Pulsar 1E 1048.1-5937. *ApJ* **580**, L143–L146 (2002). DOI 10.1086/345612
- [75] Israel, G.L., Esposito, P., Rea, N., Dall’Osso, S., Senziani, F., Romano, P., Mangano, V., Götz, D., Zane, S., Tiengo, A., Palmer, D.M., Krimm, H., Gehrels, N., Mereghetti, S., Stella, L., Turolla, R., Campana, S., Perna, R., Angelini, L., De Luca, A.: The 2008 October Swift detection of X-ray bursts/outburst from the transient SGR-like AXP 1E 1547.0-5408. *MNRAS* **408**, 1387–1395 (2010)
  - [76] Israel, G.L., Götz, D., Zane, S., Dall’Osso, S., Rea, N., Stella, L.: Linking the X-ray timing and spectral properties of the glitching AXP 1RXS J170849-400910. *A&A* **476**, L9–L12 (2007). DOI 10.1051/0004-6361:20078215
  - [77] Israel, G.L., Mereghetti, S., Stella, L.: The discovery of 8.7 second pulsations from the ultrasoft X-ray source 4U 0142+61. *ApJ* **433**, L25–L28 (1994)
  - [78] Israel, G.L., Oosterbroek, T., Angelini, L., Campana, S., Mereghetti, S., Parmar, A.N., Segreto, A., Stella, L., van Paradijs, J., White, N.E.: BeppoSAX monitoring of the “anomalous” X-ray pulsar 4U 0142+61. *A&A* **346**, 929–935 (1999)
  - [79] Israel, G.L., Rea, N., Mangano, V., Testa, V., Perna, R., Hummel, W., Mignani, R., Ageorges, N., Lo Curto, G., Marco, O., Angelini, L., Campana, S., Covino, S., Marconi, G., Mereghetti, S., Stella, L.: Accurate X-Ray Position of the Anomalous X-Ray Pulsar XTE J1810-197 and Identification of Its Likely Infrared Counterpart. *ApJ* **603**, L97–L100 (2004). DOI 10.1086/382875
  - [80] Israel, G.L., Rea, N., Rol, E., Mignani, R., Testa, V., Stella, L., Esposito, P., Mereghetti, S., Tiengo, A., Marconi, G., Burgay, M., Possenti, A., Zane, S.: ESO-VLT discovery of the variable nIR counterpart to the AXP 1E1547.0-5408. *Astron. Tel.* **1909** (2009)
  - [81] Juett, A.M., Marshall, H.L., Chakrabarty, D., Schulz, N.S.: Chandra High-Resolution Spectrum of the Anomalous X-Ray Pulsar 4U 0142+61. *ApJ* **568**, L31–L34 (2002). DOI 10.1086/340273
  - [82] Kaneko, Y., Göğüş, E., Kouveliotou, C., Granot, J., Ramirez-Ruiz, E., van der Horst, A.J., Watts, A.L., Finger, M.H., Gehrels, N., Pe’er, A., van der Klis, M., von Kienlin, A., Wachter, S., Wilson-Hodge, C.A., Woods, P.M.: Magnetar Twists: Fermi/Gamma-Ray Burst Monitor Detection of SGR J1550-5418. *ApJ* **710**, 1335–1342 (2010). DOI 10.1088/0004-637X/710/2/1335
  - [83] Kaspi, V.M., Gavriil, F.P., Woods, P.M., Jensen, J.B., Roberts, M.S.E., Chakrabarty, D.: A Major Soft Gamma Repeater-like Outburst and Rotation Glitch in the No-longer-so-anomalous X-Ray Pulsar 1E 2259+586. *ApJ* **588**, L93–L96 (2003)
  - [84] Kern, B., Martin, C.: Optical pulsations from the anomalous X-ray pulsar 4U0142+61. *Nature* **417**, 527–529 (2002)
  - [85] Kosugi, G., Ogasawara, R., Terada, H.: A Variable Infrared Counterpart to the Soft Gamma-Ray Repeater SGR 1806-20. *ApJ* **623**, L125–L128 (2005). DOI 10.1086/430171

- [86] Kouveliotou, C., Dieters, S., Strohmayer, T., van Paradijs, J., Fishman, G.J., Meegan, C.A., Hurley, K., Kommers, J., Smith, I., Frail, D., Murakami, T.: An X-ray pulsar with a superstrong magnetic field in the soft gamma-ray repeater SGR 1806-20. *Nature* **393**, 235–237 (1998)
- [87] Kouveliotou, C., Eichler, D., Woods, P.M., Lyubarsky, Y., Patel, S.K., Göğüş, E., van der Klis, M., Tennant, A., Wachter, S., Hurley, K.: Unraveling the Cooling Trend of the Soft Gamma Repeater SGR 1627-41. *ApJ* **596**, L79–L82 (2003)
- [88] Kuiper, L., den Hartog, P.R., Hermesen, W.: The INTEGRAL detection of pulsed soft gamma-rays from SGR/AXP 1E1547.0-5408 during its Jan-2009 outburst. *The Astronomer’s Telegram* **1921** (2009)
- [89] Kuiper, L., Hermesen, W., den Hartog, P.R., Collmar, W.: Discovery of Luminous Pulsed Hard X-Ray Emission from Anomalous X-Ray Pulsars 1RXS J1708-4009, 4U 0142+61, and 1E 2259+586 by INTEGRAL and RXTE. *ApJ* **645**, 556–575 (2006). DOI 10.1086/504317
- [90] Kuiper, L., Hermesen, W., Mendez, M.: Discovery of Hard Nonthermal Pulsed X-Ray Emission from the Anomalous X-Ray Pulsar 1E 1841-045. *ApJ* **613**, 1173–1178 (2004). DOI 10.1086/423129
- [91] Kumar, H.S., Safi-Harb, S.: Variability of the High Magnetic Field X-Ray Pulsar PSR J1846-0258 Associated with the Supernova Remnant Kes 75 as Revealed by the Chandra X-Ray Observatory. *ApJ* **678**, L43–L46 (2008). DOI 10.1086/588284
- [92] Kumar, H.S., Safi-Harb, S.: Swift Study of the First Soft  $\gamma$ -ray Repeater Like Burst from AXP 1E 1841-045 in SNR Kes 73. *ApJ* **725**, L191–L195 (2010). DOI 10.1088/2041-8205/725/2/L191
- [93] Laros, J.G., Fenimore, E.E., Fikani, M.M., Klebesadel, R.W., Barat, C.: The soft gamma-ray burst GB790107. *Nature* **322**, 152 (1986)
- [94] Laros, J.G., Fenimore, E.E., Klebesadel, R.W., Atteia, J.L., Boer, M., Hurley, K., Niel, M., Vedrenne, G., Kane, S.R., Kouveliotou, C., Cline, T.L., Dennis, B.R., Desai, U.D., Orwig, L.E., Kuznetsov, A.V., Sunyaev, R.A., Terekhov, O.V.: A new type of repetitive behavior in a high-energy transient. *ApJ* **320**, L111–L115 (1987). DOI 10.1086/184985
- [95] Leahy, D.A., Tian, W.W.: The distance of the SNR Kes 75 and PWN PSR J1846-0258 system. *A&A* **480**, L25–L28 (2008). DOI 10.1051/0004-6361:20079149
- [96] Levin, L., Bailes, M., Bates, S., Bhat, N.D.R., Burgay, M., Burke-Spolaor, S., D’Amico, N., Johnston, S., Keith, M., Kramer, M., Milia, S., Possenti, A., Rea, N., Stappers, B., van Straten, W.: A Radio-loud Magnetar in X-ray Quiescence. *ApJ* **721**, L33–L37 (2010)
- [97] Manchester, R.N.: Observational Properties of Pulsars. *Science* **304**, 542–547 (2004). DOI 10.1126/science.1097649
- [98] Mande, M., Balasis, G.: The SGR 1806-20 magnetar signature on the Earth’s magnetic field. *Geophysical Journal International* **167**, 586–591 (2006). DOI 10.1111/j.1365-246X.2006.03125.x

- [99] McBride, V.A., Dean, A.J., Bazzano, A., Bird, A.J., Hill, A.B., de Rosa, A., Landi, R., Sguera, V., Malizia, A.: INTEGRAL detection of the pulsar wind nebula in PSR J1846-0258. *A&A* **477**, 249–253 (2008). DOI 10.1051/0004-6361:20078432
- [100] McClure-Griffiths, N.M., Gaensler, B.M.: Constraints on the Distance to SGR 1806-20 from H I Absorption. *ApJ* **630**, L161–L163 (2005). DOI 10.1086/496879
- [101] Mereghetti, S.: The strongest cosmic magnets: soft gamma-ray repeaters and anomalous X-ray pulsars. *A&A Rev.* **15**, 225–287 (2008). DOI 10.1007/s00159-008-0011-z
- [102] Mereghetti, S., Esposito, P., Tiengo, A.: XMM Newton observations of soft gamma-ray repeaters. *Ap&SS* **308**, 13–23 (2007). DOI 10.1007/s10509-007-9384-0
- [103] Mereghetti, S., Esposito, P., Tiengo, A., Turolla, R., Zane, S., Stella, L., Israel, G.L., Feroci, M., Treves, A.: XMM-Newton observations of the Soft Gamma Ray Repeater SGR 1627-41 in a low luminosity state. *A&A* **450**, 759–762 (2006). DOI 10.1051/0004-6361:20054210
- [104] Mereghetti, S., Esposito, P., Tiengo, A., Zane, S., Turolla, R., Stella, L., Israel, G.L., Götz, D., Feroci, M.: The First XMM-Newton Observations of the Soft Gamma-Ray Repeater SGR 1900+14. *ApJ* **653**, 1423–1428 (2006). DOI 10.1086/508682
- [105] Mereghetti, S., Götz, D., von Kienlin, A., Rau, A., Lichti, G., Weidenspointner, G., Jean, P.: The First Giant Flare from SGR 1806-20: Observations Using the Anticoincidence Shield of the Spectrometer on INTEGRAL. *ApJ* **624**, L105–L108 (2005). DOI 10.1086/430669
- [106] Mereghetti, S., Götz, D., Weidenspointner, G., von Kienlin, A., Esposito, P., Tiengo, A., Vianello, G., Israel, G.L., Stella, L., Turolla, R., Rea, N., Zane, S.: Strong Bursts from the Anomalous X-Ray Pulsar 1E 1547.0-5408 Observed with the INTEGRAL/SPI Anti-Coincidence Shield. *ApJ* **696**, L74–L78 (2009). DOI 10.1088/0004-637X/696/1/L74
- [107] Mereghetti, S., Stella, L.: The very low mass X-ray binary pulsars: A new class of sources? *ApJ* **442**, L17–L20 (1995)
- [108] Mereghetti, S., Tiengo, A., Esposito, P., Götz, D., Stella, L., Israel, G.L., Rea, N., Feroci, M., Turolla, R., Zane, S.: An XMM-Newton View of the Soft Gamma Repeater SGR 1806-20: Long-Term Variability in the Pre-Giant Flare Epoch. *ApJ* **628**, 938–945 (2005). DOI 10.1086/430943
- [109] Mereghetti, S., Tiengo, A., Stella, L., Israel, G.L., Rea, N., Zane, S., Oosterbroek, T.: Pronounced Long-Term Flux Variability of the Anomalous X-Ray Pulsar 1E 1048.1-5937. *ApJ* **608**, 427–431 (2004)
- [110] Mignani, R.P.: Optical, ultraviolet, and infrared observations of isolated neutron stars. *Advances in Space Research*, in press, preprint (arXiv:astro-ph/0912.2931) (2010)
- [111] Mignani, R.P., Rea, N., Testa, V., Israel, G.L., Marconi, G., Mereghetti, S., Jonker, P., Turolla, R., Perna, R., Zane, S., Lo Curto, G., Chaty, S.: VLT/NACO near-infrared observations of the transient radio magnetar 1E

- 1547.0-5408. *A&A* **497**, 451–455 (2009). DOI 10.1051/0004-6361/200811270
- [112] Morii, M., Sato, R., Kataoka, J., Kawai, N.: Chandra Observation of the Anomalous X-Ray Pulsar 1E 1841-045. *PASJ* **55**, L45–L48 (2003)
- [113] Munro, M.P., Clark, J.S., Crowther, P.A., Dougherty, S.M., de Grijs, R., Law, C., McMillan, S.L.W., Morris, M.R., Negueruela, I., Pooley, D., Portegies Zwart, S., Yusef-Zadeh, F.: A Neutron Star with a Massive Progenitor in Westerlund 1. *ApJ* **636**, L41–L44 (2006). DOI 10.1086/499776
- [114] Munro, M.P., Gaensler, B.M., Clark, J.S., de Grijs, R., Pooley, D., Stevens, I.R., Portegies Zwart, S.F.: Exciting the magnetosphere of the magnetar CXOU J164710.2-455216 in Westerlund 1. *MNRAS* **378**, L44–L48 (2007). DOI 10.1111/j.1745-3933.2007.00317.x
- [115] Murakami, T., Tanaka, Y., Kulkarni, S.R., Ogasaka, Y., Sonobe, T., Ogawara, Y., Aoki, T., Yoshida, A.: X-Ray Identification of the Soft Gamma-Ray Repeater 1806-20. *Nature* **368**, 127 (1994)
- [116] Ng, C., Kaspi, V.M., Dib, R., Olausen, S.A., Scholz, P., Guver, T., Ozel, F., Gavril, F.P., Woods, P.M.: Chandra and RXTE Observations of 1E 1547.0-5408: Comparing the 2008 and 2009 Outbursts. *ApJ*, in press (preprint: astro-ph/1008.1165) (2010)
- [117] Ng, C., Slane, P.O., Gaensler, B.M., Hughes, J.P.: Deep Chandra Observation of the Pulsar Wind Nebula Powered by Pulsar PSR J1846-0258 in the Supernova Remnant Kes 75. *ApJ* **686**, 508–519 (2008). DOI 10.1086/591146
- [118] Nobili, L., Turolla, R., Zane, S.: X-ray spectra from magnetar candidates - I. Monte Carlo simulations in the non-relativistic regime. *MNRAS* **386**, 1527–1542 (2008). DOI 10.1111/j.1365-2966.2008.13125.x
- [119] Paczynski, B.: GB 790305 as a very strongly magnetized neutron star. *Acta Astronomica* **42**, 145–153 (1992)
- [120] Palmer, D.M., Barthelmy, S., Gehrels, N., Kippen, R.M., Cayton, T., Kouveliotou, C., Eichler, D., Wijers, R.A.M.J., Woods, P.M., Granot, J., Lyubarsky, Y.E., Ramirez-Ruiz, E., Barbier, L., Chester, M., Cummings, J., Fenimore, E.E., Finger, M.H., Gaensler, B.M., Hullinger, D., Krimm, H., Markwardt, C.B., Nousek, J.A., Parsons, A., Patel, S., Sakamoto, T., Sato, G., Suzuki, M., Tueller, J.: A giant  $\gamma$ -ray flare from the magnetar SGR 1806 - 20. *Nature* **434**, 1107–1109 (2005). DOI 10.1038/nature03525
- [121] Patel, S.K., Kouveliotou, C., Woods, P.M., Tennant, A.F., Weisskopf, M.C., Finger, M.H., Wilson, C.A., Göğüş, E., van der Klis, M., Belloni, T.: Chandra Observations of the Anomalous X-Ray Pulsar 4U 0142+61. *ApJ* **587**, 367–372 (2003). DOI 10.1086/368072
- [122] Paul, B., Kawasaki, M., Dotani, T., Nagase, F.: Study of the Long-Term Stability of Two Anomalous X-Ray Pulsars, 4U 0142+61 and 1E 1048.1-5937, with ASCA. *ApJ* **537**, 319–326 (2000). DOI 10.1086/309028
- [123] Perna, R., Hernquist, L., Narayan, R.: Emission Spectra of Fallback Disks around Young Neutron Stars. *ApJ* **541**, 344–350 (2000). DOI 10.1086/309404

- [124] Perna, R., Pons, J.A.: A Unified Model of the Magnetar and Radio Pulsar Bursting Phenomenology. *ApJ* **727**, L51 (2011). DOI 10.1088/2041-8205/727/2/L51
- [125] Rea, N., Esposito, P., Turolla, R., Israel, G.L., Zane, S., Stella, L., Mereghetti, S., Tiengo, A., Götz, D., Göğüş, E., Kouveliotou, C.: A Low-Magnetic-Field Soft Gamma Repeater. *Science* **330**, 944–945 (2010). DOI 10.1126/science.1196088
- [126] Rea, N., Israel, G., Covino, S., Tiengo, A., Nichelli, E., Turolla, R., Zane, S., Mereghetti, S., Esposito, P., Stella, L.: SGR 1806-20: X-ray and IR post-Giant Flare monitoring. *Astron. Tel.* 645 (2005)
- [127] Rea, N., Israel, G.L., Turolla, R., Esposito, P., Mereghetti, S., Götz, D., Zane, S., Tiengo, A., Hurley, K., Feroci, M., Still, M., Yershov, V., Winkler, C., Perna, R., Bernardini, F., Ubertini, P., Stella, L., Campana, S., van der Klis, M., Woods, P.: The first outburst of the new magnetar candidate SGR 0501+4516. *MNRAS* **396**, 2419–2432 (2009). DOI 10.1111/j.1365-2966.2009.14920.x
- [128] Rea, N., Nichelli, E., Israel, G.L., Perna, R., Oosterbroek, T., Parmar, A.N., Turolla, R., Campana, S., Stella, L., Zane, S., Angelini, L.: Very deep X-ray observations of the anomalous X-ray pulsar 4U0142+614. *MNRAS* **381**, 293–300 (2007). DOI 10.1111/j.1365-2966.2007.12257.x
- [129] Rea, N., Testa, V., Israel, G.L., Mereghetti, S., Perna, R., Stella, L., Tiengo, A., Mangano, V., Oosterbroek, T., Mignani, R., Lo Curto, G., Campana, S., Covino, S.: Correlated Infrared and X-ray variability of the transient Anomalous X-ray Pulsar XTE J1810-197. *A&A* **425**, L5–L8 (2004). DOI 10.1051/0004-6361:200400052
- [130] Rea, N., Oosterbroek, T., Zane, S., Turolla, R., Méndez, M., Israel, G. L., Stella, L., Haberl, F.: Post-glitch variability in the anomalous X-ray pulsar 1RXSJ170849.0-400910. *MNRAS* **361**, 710–718 (2005). DOI 10.1111/j.1365-2966.2005.09201.x
- [131] Rea, N., Israel, G. L., Stella, L., Oosterbroek, T., Mereghetti, S., Angelini, L., Campana, S., Covino, S.: Evidence of a Cyclotron Feature in the Spectrum of the Anomalous X-Ray Pulsar 1RXS J170849-400910. *ApJ* **586**, L65–L69 (2003). DOI 10.1086/374585
- [132] Rea, N., Tiengo, A., Mereghetti, S., Israel, G.L., Zane, S., Turolla, R., Stella, L.: A First Look with Chandra at SGR 1806-20 after the Giant Flare: Significant Spectral Softening and Rapid Flux Decay. *ApJ* **627**, L133–L136 (2005). DOI 10.1086/431951
- [133] Rea, N., Turolla, R., Zane, S., Tramacere, A., Stella, L., Israel, G.L., Campana, R.: Spectral Modeling of the High-Energy Emission of the Magnetar 4U 0142+614. *ApJ* **661**, L65–L68 (2007). DOI 10.1086/518434
- [134] Rea, N., Zane, S., Turolla, R., Lyutikov, M., Götz, D.: Resonant Cyclotron Scattering in Magnetars’ Emission. *ApJ* **686**, 1245–1260 (2008). DOI 10.1086/591264
- [135] Rol, E., Tanvir, N., Rea, N., Wiersema, K., Skillen, I., Curran, P.A.: NIR observations of Sgr 0501+4516. *GCN Circ.* **8164** (2008)

- [136] Savchenko, V., Neronov, A., Beckmann, V., Produit, N., Walter, R.: SGR-like flaring activity of the anomalous X-ray pulsar 1E 1547.0-5408. *A&A* **510**, A77+ (2010). DOI 10.1051/0004-6361/200911988
- [137] Seward, F.D., Charles, P.A., Smale, A.P.: A 6 second periodic X-ray source in Carina. *ApJ* **305**, 814–816 (1986). DOI 10.1086/164294
- [138] Tam, C.R., Gavriil, F.P., Dib, R., Kaspi, V.M., Woods, P.M., Bassa, C.: X-Ray and Near-IR Variability of the Anomalous X-Ray Pulsar 1E 1048.1-5937: From Quiescence Back to Activity. *ApJ* **677**, 503–514 (2008). DOI 10.1086/528368
- [139] Tam, C.R., Kaspi, V.M., Gaensler, B.M., Gotthelf, E.V.: Chandra Observations of the Transient 7 s X-ray Pulsar AX J1845.0-0258. *ApJ* **652**, 548–553 (2006). DOI 10.1086/507262
- [140] Tam, C.R., Kaspi, V.M., van Kerkwijk, M.H., Durant, M.: Correlated Infrared and X-Ray Flux Changes Following the 2002 June Outburst of the Anomalous X-Ray Pulsar 1E 2259+586. *ApJ* **617**, L53–L56 (2004). DOI 10.1086/426963
- [141] Taylor, G.B., Gelfand, J.D., Gaensler, B.M., Granot, J., Kouveliotou, C., Fender, R.P., Ramirez-Ruiz, E., Eichler, D., Lyubarsky, Y.E., Garrett, M., Wijers, R.A.M.J.: The Growth, Polarization, and Motion of the Radio Afterglow from the Giant Flare from SGR 1806-20. *ApJ* **634**, L93–L96 (2005). DOI 10.1086/491648
- [142] Testa, V., Rea, N., Mignani, R.P., Israel, G.L., Perna, R., Chaty, S., Stella, L., Covino, S., Turolla, R., Zane, S., Lo Curto, G., Campana, S., Marconi, G., Mereghetti, S.: Adaptive optics, near-infrared observations of magnetars. *A&A* **482**, 607–615 (2008). DOI 10.1051/0004-6361:20078692
- [143] Thompson C., Lyutikov M., Kulkarni S. R.: Electrodynamics of Magnetars: Implications for the Persistent X-ray Emission and Spin-down of the Soft Gamma Repeaters and Anomalous X-ray Pulsars. *ApJ* **574**, 332–355 (2002)
- [144] Thompson, C., Duncan, R.C.: Neutron star dynamos and the origins of pulsar magnetism. *ApJ* **408**, 194–217 (1993). DOI 10.1086/172580
- [145] Tiengo, A., Esposito, P., Mereghetti, S.: XMM-Newton Observations of CXOU J010043.1-721134: The First Deep Look at the Soft X-Ray Emission of a Magnetar. *ApJ* **680**, L133–L136 (2008). DOI 10.1086/590078
- [146] Tiengo, A., Esposito, P., Mereghetti, S., Israel, G.L., Stella, L., Turolla, R., Zane, S., Rea, N., Götz, D., Feroci, M.: Quiet but still bright: XMM-Newton observations of the soft gamma-ray repeater SGR 0526-66. *MNRAS* **399**, L74–L78 (2009). DOI 10.1111/j.1745-3933.2009.00728.x
- [147] Tiengo, A., Esposito, P., Mereghetti, S., Rea, N., Stella, L., Israel, G.L., Turolla, R., Zane, S.: The calm after the storm: XMM-Newton observation of SGR 1806-20 two months after the Giant Flare of 2004 December 27. *A&A* **440**, L63–L66 (2005). DOI 10.1051/0004-6361:200500170
- [148] Tiengo, A., Mereghetti, S., Turolla, R., Zane, S., Rea, N., Stella, L., Israel, G.L.: Three XMM-Newton observations of the anomalous X-ray pulsar 1E 1048.1-5937: Long term variations in spectrum and pulsed fraction. *A&A* **437**, 997–1005 (2005). DOI 10.1051/0004-6361:20052633



- [149] Tiengo, A., Vianello, G., Esposito, P., Mereghetti, S., Giuliani, A., Costantini, E., Israel, G.L., Stella, L., Turolla, R., Zane, S., Rea, N., Götz, D., Bernardini, F., Moretti, A., Romano, P., Ehle, M., Gehrels, N.: The Dust-scattering X-ray Rings of the Anomalous X-ray Pulsar 1E 1547.0-5408. *ApJ* **710**, 227–235 (2010). DOI 10.1088/0004-637X/710/1/227
- [150] Torii, K., Kinugasa, K., Katayama, K., Tsunemi, H., Yamauchi, S.: Discovery of a 7 Second X-Ray Pulsar, AX J1845.0-0300. *ApJ* **503**, 843 (1998). DOI 10.1086/306038
- [151] van der Horst, A.J., Connaughton, V., Kouveliotou, C., Göğüş, E., Kaneko, Y., Wachter, S., Briggs, M.S., Granot, J., Ramirez-Ruiz, E., Woods, P.M., Aptekar, R.L., Barthelmy, S.D., Cummings, J.R., Finger, M.H., Frederiks, D.D., Gehrels, N., Gelino, C.R., Gelino, D.M., Golenetskii, S., Hurley, K., Krimm, H.A., Mazets, E.P., McEnery, J.E., Meegan, C.A., Oleynik, P.P., Palmer, D.M., Pal'shin, V.D., Pe'er, A., Svinkin, D., Ulanov, M.V., van der Klis, M., von Kienlin, A., Watts, A.L., Wilson-Hodge, C.A.: Discovery of a New Soft Gamma Repeater: SGR J0418 + 5729. *ApJ* **711**, L1–L6 (2010). DOI 10.1088/2041-8205/711/1/L1
- [152] van Paradijs, J., Taam, R.E., van den Heuvel, E.P.J.: On the nature of the 'anomalous' 6-s X-ray pulsars. *A&A* **299**, L41 (1995)
- [153] Vasisht, G., Gotthelf, E.V., Torii, K., Gaensler, B.M.: Detection of a Compact X-Ray Source in the Supernova Remnant G29.6+0.1: A Variable Anomalous X-Ray Pulsar? *ApJ* **542**, L49–L52 (2000). DOI 10.1086/312910
- [154] Vasisht, G., Kulkarni, S.R., Frail, D.A., Greiner, J.: Supernova remnant candidates for the soft gamma-ray repeater 1900+14. *ApJ* **431**, L35–L38 (1994)
- [155] Wang, Z., Bassa, C., Kaspi, V.M., Bryant, J.J., Morrell, N.: Optical/Infrared Observations of the Anomalous X-Ray Pulsar 1E 1048.1-5937 During Its 2007 X-Ray Flare. *ApJ* **679**, 1443–1446 (2008). DOI 10.1086/587505
- [156] Wang, Z., Chakrabarty, D.: The Likely Near-Infrared Counterpart to the Anomalous X-Ray Pulsar 1E 1048.1-5937. *ApJ* **579**, L33–L36 (2002)
- [157] Wang, Z., Chakrabarty, D., Kaplan, D.L.: A debris disk around an isolated young neutron star. *Nature* **440**, 772–775 (2006). DOI 10.1038/nature04669
- [158] White, N.E., Mason, K.O., Giommi, P., Angelini, L., Pooley, G., Branduardi-Raymont, G., Murdin, P.G., Wall, J.V.: A 25 min modulation from the vicinity of the unusually soft X-ray source X0142+614. *MNRAS* **226**, 645–654 (1987)
- [159] Wilson, C.A., Dieters, S., Finger, M.H., Scott, D.M., van Paradijs, J.: Rossi X-Ray Timing Explorer Observations of the Anomalous Pulsar 4U 0142+61. *ApJ* **513**, 464–470 (1999). DOI 10.1086/306839
- [160] Woods, P.M., Kaspi, V.M., Gavriil, F.P., Airhart, C.: The 2006 Outburst of the Magnetar CXOU J164710.2-455216. *ApJ* **726**, 37 (2011). DOI 10.1088/0004-637X/726/1/37
- [161] Woods, P.M., Kaspi, V.M., Thompson, C., Gavriil, F.P., Marshall, H.L., Chakrabarty, D., Flanagan, K., Heyl, J., Hernquist, L.: Changes in the X-Ray Emission from the Magnetar Candidate 1E 2259+586 during Its 2002 Outburst. *ApJ* **605**, 378–399 (2004)

- [162] Woods, P.M., Kouveliotou, C., Finger, M.H., Göğüş, E., Wilson, C.A., Patel, S.K., Hurley, K., Swank, J.H.: The Prelude to and Aftermath of the Giant Flare of 2004 December 27: Persistent and Pulsed X-Ray Properties of SGR 1806-20 from 1993 to 2005. *ApJ* **654**, 470–486 (2007). DOI 10.1086/507459
- [163] Woods, P.M., Kouveliotou, C., van Paradijs, J., Hurley, K., Kippen, R.M., Finger, M.H., Briggs, M.S., Dieters, S., Fishman, G.J.: Discovery of a New Soft Gamma Repeater, SGR 1627-41. *ApJ* **519**, L139–L142 (1999)
- [164] Zane, S., Rea, N., Turolla, R., Nobili, L.: X-ray spectra from magnetar candidates - III. Fitting SGR/AXP soft X-ray emission with non-relativistic Monte Carlo models. *MNRAS* **398**, 1403–1413 (2009). DOI 10.1111/j.1365-2966.2009.15190.x